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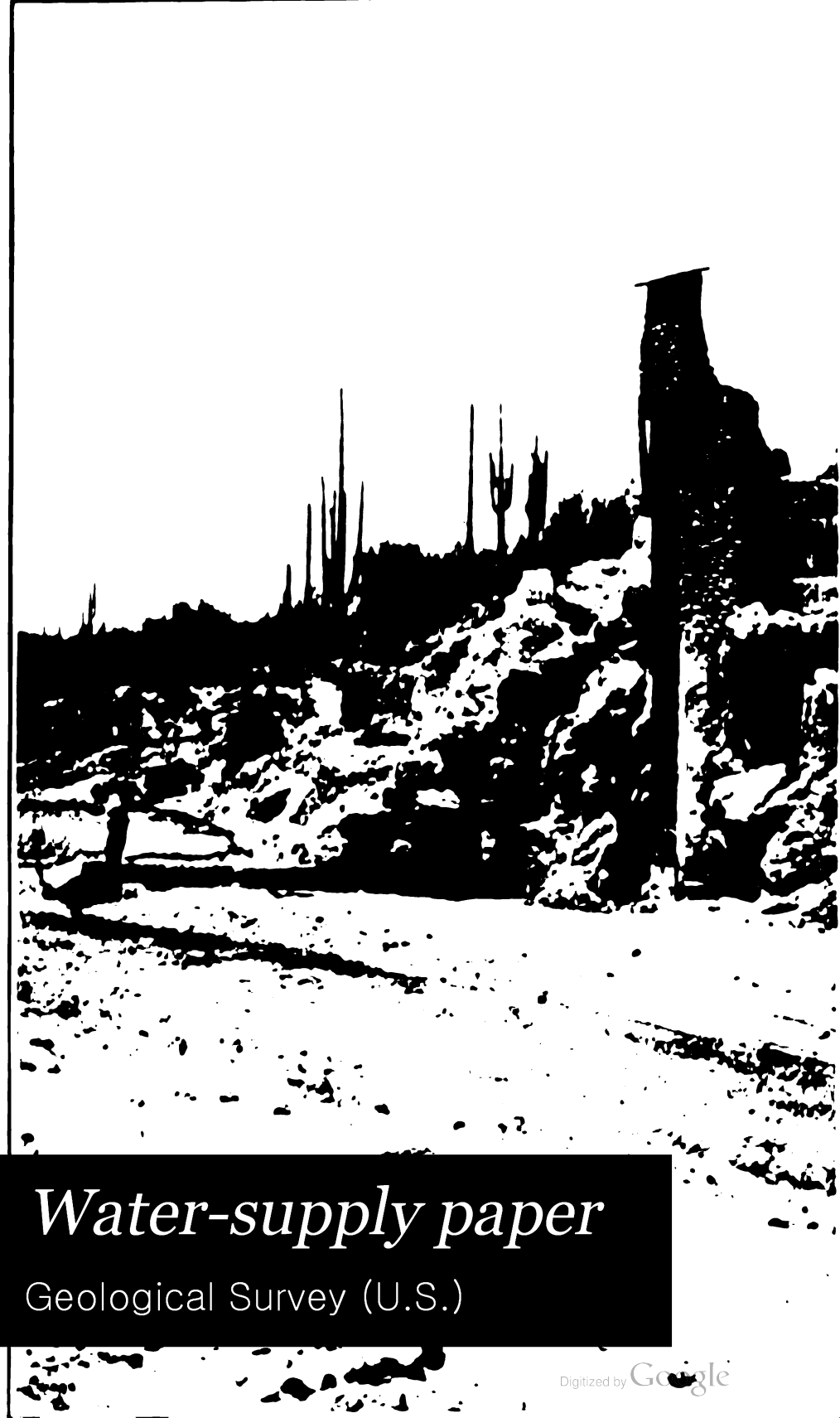

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EQUIPMENT FOR CURRENT-METER GAGING STATIONS

BY

G. J. LYON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

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EQUIPMENT FOR CURRENT-METER GAGING STATIONS.

By G. J. Lyon.

ITEMS OF EQUIPMENT.

Gaging stations for determining the total flow of a stream and its diurnal fluctuation need, in general, the following equipment:

1. A gage or gages for determining fluctuations of stage.
2. Bench marks for referring the gages to a fixed datum.
3. Structures from which discharge measurements are made.
4. Cable and stay line to hold the meter in a vertical position when soundings and velocity observations are made.
5. Graduated lines to indicate the points of measurement.
6. Artificial structures, at places where natural control is ineffective, to regulate the relation between stage and discharge.

Although no one form of any of these items is indispensable, there are certain standard types that can, as a rule, be most economically installed and that not only facilitate the making of observations but insure more accurate results. It is expected that details of construction will be adjusted to local conditions.

The types of equipment that had been found most effective were described in a pamphlet entitled "Plans and specifications for current-meter gaging streams," by C. C. Covert, G. J. Lyon, and C. H. Pierce, issued by the Survey in 1912. The matter presented in that pamphlet has been revised and expanded to include the latest and best available information in regard to the subject, and is embodied in this report, which comprises also suggestions from several hydraulic engineers, to whom acknowledgment is hereby made.

GAGES.

CLASSIFICATION.

The instruments that have been used for measuring fluctuations of stage of rivers and other bodies of water may be grouped into two general classes, comprising, respectively, nonrecording gages and recording gages, the grouping depending on the method of obtaining the record, whether by direct readings at stated intervals from a scale board or other device or by some automatic mechanism.

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Recording gages make a record of stage, either continuously by a curve, the coordinates of which indicate the time and the stage, or by a device that prints at regular intervals of time. Nonrecording gages in common use are the vertical-staff gage, the hook gage, the float gage, the chain gage, and the inclined-staff gage.

NONRECORDING GAGES.

VERTICAL-STAFF GAGE.

The best vertical-staff gage (Pl. I, *A* and *B*) consists of a 2 by 6 inch (or larger) timber, fastened vertically to a rigid support or set upright in a concrete base which is placed in the stream bed below low water. Enameled metal sections (Pl. I, *A*, 2) on which the graduations are stamped are screwed to this timber with round-headed brass screws and leather washers. As a substitute for the enameled face a graduated board may be used, if made in 5-foot sections of 1 by 4 inch pine, painted white, with V-shaped notches, painted black, clearly indicating all foot and tenth marks (Pl. I, *A*, 3). A special tool and guide for cutting the graduations in wooden scaleboards is shown in figure 1. The graduations may also be marked by means of barrel-hoop staples.

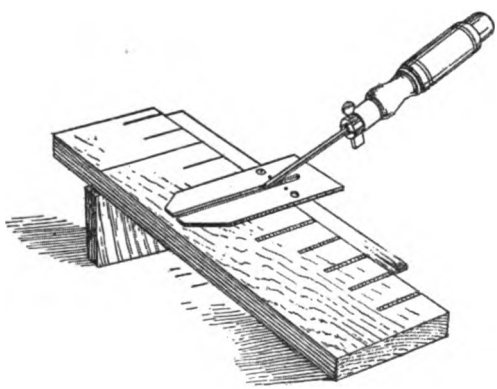

FIGURE 1.—Gage-cutting tool.

A cast-iron face (Pl. I, *A*, 4), that is especially desirable where the gage is permanent, is made in foot sections and is marked from 0 to 10 feet by raised figures that are painted either red or white to make them stand out on the black background of the gage. Plate I, *B*, shows a combined vertical and inclined staff gage on Delaware River at Port Jervis, N. Y.

HOOK GAGE.

A simple form of hook gage (Pl. I, *A*, 1) consists of a movable staff, graduated to feet, from 0 downward, with a hook at the bottom, the staff being arranged to slide against a 1-foot New York level-rod scale, which is screwed to a base and is graduated to hundredths of a foot, from 0 upward. The stage is determined by drawing the point of the hook to the surface of the water and reading on the movable staff the foot mark that is opposite the fixed scale from which the tenths and hundredths are read.

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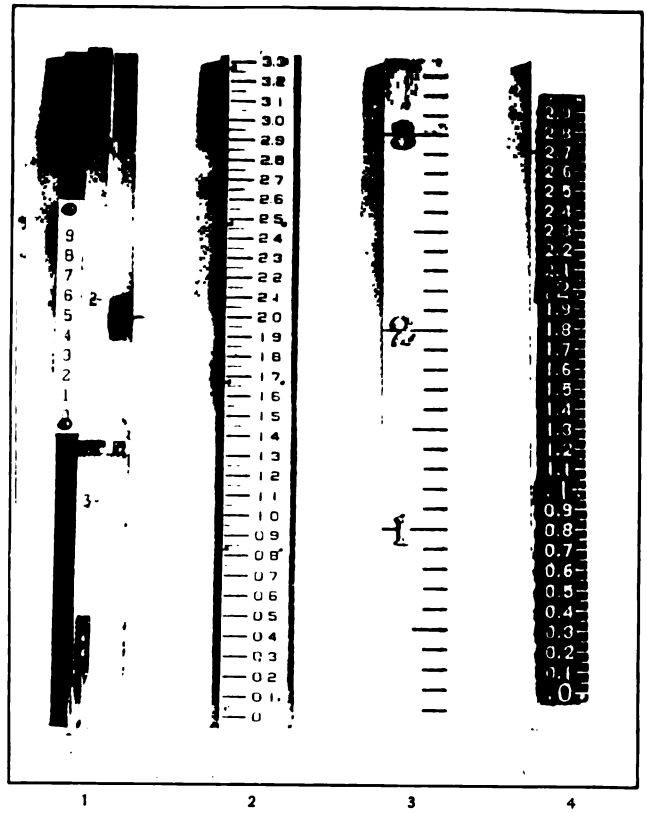
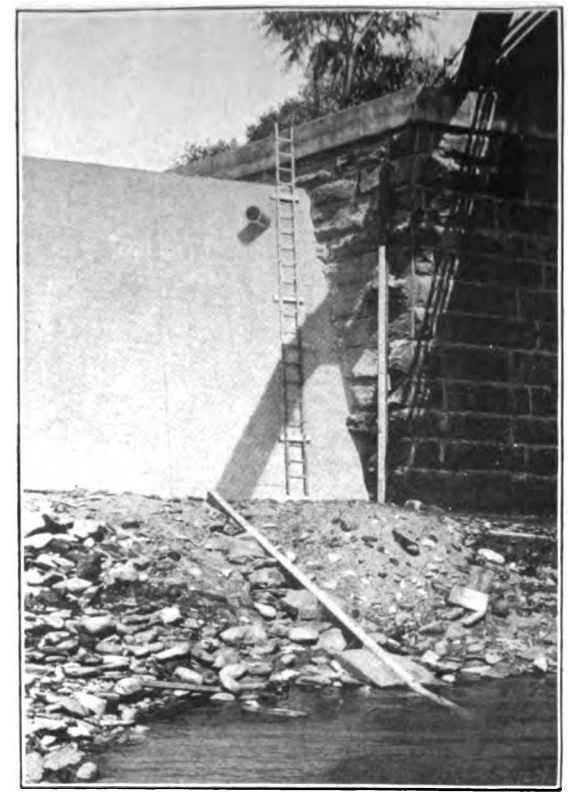


A. VERTICAL-STAFF AND HOOK GAGES.



B. VERTICAL AND INCLINED STAFF GAGES.

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TABLE 1.—*Bill of material for standard hook gage.*

[Lettered items refer to Plate VIII, p. 20.]

Item 1. One ¾ by 2 inch hook gage rod, of proper length.
2. One set standard lugs *L*, with 1¼-inch No. 9 brass screws.
3. One window latch *K*, with screws.
4. One standard hook *Z*, with brass screws.
5. One standard scale *Z*1, with screws and washers.
6. One piece cypress, or other wood, 2 by 6 inches, for bed piece, for hook gage.

FLOAT GAGE.

The float gage is similar to the hook gage, except that the hook at the bottom of the movable staff is replaced by a float which rises and falls with the fluctuations in stage and carries the staff with it. The readings are made in the manner described for the hook gage.

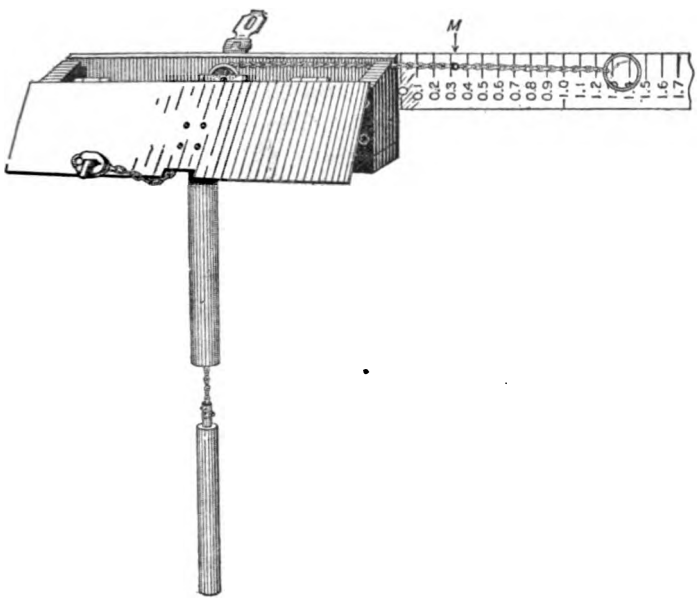

FIGURE 2.—Chain-gage equipment.

CHAIN GAGE.

The chain gage, shown in figure 2, consists of a graduated scale 10 feet or more in length, usually either extending from or contained in a box supporting a pulley wheel over which runs a heavy sash chain carrying at one end a weight and near the other end a marker *M*, shown on the scale between the 0.3 graduation and the 0.4 graduation. Sections of the standard enameled metal gage may be used for the graduated scale. This gage as a whole is fastened horizontally to a rigid structure, so that the weight when lowered will come in contact with moving water. When such contact is made the reading on the scale board opposite the marker is recorded.

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The gage weight (Pl. II) is made of an iron bar, 13 inches long, squarely off on each end. For a distance of 1¾ inches from one e the bar is turned down to an external diameter of three-fourths an inch. In the end of this reduced section a half-inch hole bored to a depth of 3 inches, and, beginning at a point three-eigh of an inch from the end, a series of $\frac{3}{32}$-inch holes are bored along axis of the weight. These holes are spaced exactly one one-hu dredth foot apart, and each hole is placed at an angle of 60° in pl to the one above it. These holes, which receive the cotter pin means of which the weight is hung on the sash chain, allow a required adjustment of the chain length by even hundredths of foot. The weight should then be well galvanized.

The most satisfactory chain thus far used for gages of this type Morton's Champion metal window-sash chain No. 1 regular. Th chain, if thoroughly stretched before it is put in place, will hold i length and is not sensibly affected by wearing of the parts.

Gage boxes are usually made of first-class cypress or similar woo with an iron top and down spout. The outside dimensions of th box, as shown in Plate II, exclusive of the top, are as follow Length, 24 inches; width, 6 inches; height in back, 8⅛ inches; heigh in front, 5⅝ inches. The box is fastened together with bolts an screws as shown—8 screws in the bottom (3 on each side and 1 in each end) and 2 screws near the top of the box.

A hole should be bored in the bottom to permit the insertion of a 2-inch wrought-iron pipe, which should be screwed 1⅛ inches into the hole in order to fit it and then be removed for convenience in shipping. Two quarter-inch holes, placed as shown on the back piece *B* (Pl. II), should be made in the back to allow for two positions of the special open-side pulley. The two end pieces *A* should be notched as shown, so that the chain will run horizontally from the pulley past either end of the box.

The top *E* is to be made of ⅛-inch iron with 6-inch strap hinges *G* and staple for an 8-inch hasp *H* fastened to it with machine screws. The holes in the cover should be drilled and tapped to match those in the hinges and hasp.

Box and ironwork should receive two coats of mineral paint or Dixon's graphite paint, both inside and out.

The materials required are specified in Table 2.

TABLE 2.—*Bill of material for chain-gage box.*

[Lettered items refer to Plate II.]

LUMBER.

Item 1. One piece cypress, 1⅛ by 8 inches by 8 feet long, from which cut—
Two pieces *A*, ends, 3¾ by 6¼ inches.
One piece *B*, back, 7 by 24 inches.
One piece *C*, front, 5 by 24 inches.
One piece *D*, bottom, 6 by 24 inches.

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HARDWARE.

Item 2. One piece sheet iron *E*, top cover, $\frac{1}{8}$ by 7 by 24 inches.
3. Twelve flat-head machine screws, $\frac{1}{4}$ by $\frac{1}{4}$ inch.
4. One pair 6-inch strap hinges *G*, with 1-inch screws.
5. One 8-inch safety hasp *H* and staple *I*, with 1-inch wood screws.
6. Four carriage bolts *K*, $\frac{1}{4}$ by $6\frac{1}{2}$ inches, with nuts and washers, ends to be cut and riveted flush with nuts.
7. One piece 2-inch wrought-iron pipe *L*, 14 inches long, threaded one end.
8. Ten F. H. bright wood screws *N*, 2 inches by No. 12.
9. One stove bolt *O*, $\frac{1}{4}$ by $1\frac{3}{4}$ inches, round head, for holding pipe to bottom of box.
10. One open-side pulley.

INCLINED-STAFF GAGE.

ESSENTIAL FEATURES.

The inclined staff (Pl. I, *B*) is useful where there is no rigid object to which a vertical staff may be attached. It should be made of 4 by 6 inch timber, or larger, supported at short intervals on posts or concrete piers firmly set in the ground, and should be graduated by means of an engineer's level after being placed in position, so as to give readings directly.

GAGE ON CONCRETE PIERS.

The general method of installing gages on concrete piers is shown in Plate III by the profile of the river bank.

The bed pieces should be 4 by 6 inches by 12 feet, of chestnut, fir, or other timber equally suitable for the work. The top of the bed pieces should be flush with the original surface of the ground, so as to offer the minimum obstruction to ice and drift. The gage rod should be of 1 by 4 inch spruce or similar wood. The life of the timber pieces may be lengthened materially by the use of carbolineum or creosote, applied hot.

In order to afford drainage and thus to minimize the danger of the gage being disturbed by frost, the soil for a foot below and on each side of the bed piece may be removed and replaced with small stones.

Piers should reach below the frost line, and should be placed 11 feet on centers, slope measurement, thus allowing a lap of 6 inches on each end of the bed pieces. These lap joints should be so framed as to allow changes in the slopes of the bank. They should be bored for $\frac{3}{4}$-inch anchor bolts and the top piece should be countersunk so that the nut, using flat washers, and the end of the bolt will lie below the gage rod. The bolts should be of $\frac{3}{4}$-inch iron, 18 inches long, the hook being 3 inches long.

The bolts should be placed in the bed pieces, which are laid over the holes for the piers, and the concrete then filled in up to the bed pieces and allowed to set before any work is done on the rods or bolts. This part of the pier should be left rough, and in addition a few spikes

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should be stuck into the concrete to insure a bond when the top pier is finished, in accordance with the drawings, after the ga is in place. When the concrete is hard the nuts should be s down and the gage put in place with screws, breaking joints wi bed pieces.

The proper foot marks and subdivisions to indicate the wate should be located on the rod by means of an engineer's lev should be referred to the station bench mark. Feet of elevatio the rod should be divided into tenths and quarter-tenths and n by barrel-hoop staples, 1½ inches long for the foot marks, 1 inc for the tenth marks, and one-half inch long for the quarter marks, or by brass-headed tacks. Pattern numbers should b to indicate the proper marking of the foot and tenth marks. entire length of the gage may be subdivided into quarter-tent only that part of it which is required to be so divided by the t limits for the station.

The piers may be built of 1–3–5 concrete, without forms, and be circular in cross section. Type A or type B may be used, th selected depending on the nature of the soil. The material re for each installation is shown in Table 3.

TABLE 3.—*Bill of material for inclined gage on concrete piers.*

Item 1. One bed piece 4 by 6 inches by 12 feet for each section.
2. One gage-rod piece 1 by 4 inches by 12 feet for each section.
3. One piece ¾-inch iron, 18 inches long; threaded one end, 3-inch h other end, for each pier.
4. One ¾-inch flat washer for each pier.
5. One ¾-inch nut for each pier.
6. Six 2-inch No. 12 wood screws, round head, brass, for each gage-rod s
7. —— numbers for foot marks.
8. —— screws for each number.
9. —— barrel-hoop staples 1½ inches long.
10. —— barrel-hoop staples 1 inch long.
11. —— barrel-hoop staples ½ inch long.
12. —— cubic yards concrete for piers.
13. —— carbolineum for timber.

GAGE ATTACHED TO TIMBER POSTS.

The method to be followed in constructing gages on timber p is similar to that described for gages on concrete piers, the bed pi being carried as shown in the drawing for timber anchorage for s gages.

The supports should be bolted to the sills and the frame, t placed in the trenches at the proper distances. The bed pieces sho then be bolted to the 2 by 4 inch supports, as shown in the drawi after which the backfill should be thoroughly tamped into place. desired, a ¼-inch bolt may be placed in each side parallel to the b pieces through the upper end of the 2 by 4 inch supports. The ma rial required is listed in Table 4.

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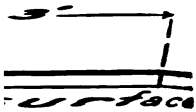

GAGE

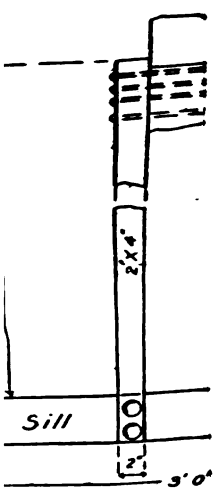

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TABLE 4.—*Bill of material for inclined gage on timber posts.*

Item 1. One bed piece 4 by 6 inches by 12 feet for each section.
2. Gage-rod piece 1 by 4 inches by 12 feet for each section.
3. Four bolts ½ by 14½ inches, with washers and nuts, for each section.
4. Four bolts ½ by 10½ inches, with washers and nuts, for each section.
5. Six 2-inch No. 12 wood screws, round head, brass, for each section.
6. —— numbers for foot marks.
7. —— screws for numbers.
8. —— barrel-hoop staples 1½ inches long.
9. —— barrel-hoop staples 1 inch long.
10. —— barrel-hoop staples ½ inch long.
11. Four pieces 2 by 4 inches by distance below frost for each section.
12. One sill 4 by 6 inches by 3 feet for each section.
13. Carbolineum for timber.

NOTE.—The plan shows the support for the intermediate joints. At the extreme end of the gage, whether one or more sections are used, only one set of 2 by 4 inch uprights are necessary, and the bolts that fasten these to the sills are ½ by 10½ inches—that is, 4 inches shorter than for the intermediate section. One more sill than the number of sections is required.

If the gage is to be installed where the stream channel is subject to material change in cross section the inclined gage on timber posts may be used, but the construction should be modified as shown in Plate III, illustrating the method of installing slope gage on shifting channels. Each section of the gage should be an independent unit, so that the minimum of reconstruction will be necessary if the gage is washed out. Two instead of four 2 by 4 inch uprights should be attached to each sill, and two sills instead of one should be provided for each intermediate gage section. The only change from Table 3 in the list of material required is the addition of an extra sill for each intermediate section.

RECORDING GAGES.

ESSENTIAL FEATURES OF INSTALLATION.

The essential parts of the recording gage are: (1) A float which rises and falls with the surface of the water; (2) a device for transferring the vertical motion of the float to the record, either directly or through a reducing mechanism; (3) the recording device; and (4) the clock. Plate IV shows types of automatic gages.

A properly installed automatic gage will give a record whose accuracy depends solely on the refinement of the instrument, but results from the best of gages will be impaired by improper installation. Much care in installation is therefore essential, and if the gage is to record stream heights during the winter and at flood stages it must be protected from freezing and from floating ice and débris.

In installing an automatic gage it is necessary to provide (1) a well for the float and an intake pipe to connect the well with the river;

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(2) a house to shelter the gage; and (3) staff or hook gages referred to permanent bench marks for use in checking the record and maintaining the datum.

In the ideal installation, illustrated in Plate V, *A*, the well and the house are far enough back from the river to be out of danger from floating ice or drift and to prevent freezing of well and pipes; a permanent ladder extending to the bottom of the well affords ready means of inspecting the float and intake pipe; the well is lined with concrete or heavy plank; the intake pipe is well below the lowest stage of the river and is provided with a screen for keeping out fish and foreign material, and where the intake pipe enters the well a valve is provided, so that the flow can be reduced if necessary to eliminate wave action; and ventilators from the well and in the gable of the roof keep house and well free from moisture. One nonrecording gage, of the type best suited to the locality, is placed in the river, on a solid foundation in the same cross section of the river as the intake pipe, and another, preferably a hook gage, is placed in the float well to aid in setting and checking the recording gage and, by comparison with the river gage, to indicate any interruption in the free communication with the river. The river gage may be dispensed with by using a reference point by means of which the elevation of the water surface can easily be determined.

Under ordinary circumstances a single intake pipe is sufficient; but where there is a possibility of a single intake being buried a series of pipes, one above the other, may be installed within the range of high and low water. On certain streams carrying silt in large quantities it has been found necessary to eliminate the intake pipe, the water entering the well as shown in Plate V, *B*, and natural cover protecting the well in the manner illustrated.

WELL AND INTAKE.

MATERIALS AND DIMENSIONS.

The well is essentially a stilling box for the float, and it is so connected with the river by an intake pipe that the height of water in the well fluctuates with the stage of the river. The well box must be large enough to accommodate the float, the driving and counter weights, and the hook or staff gage and to permit them to be inspected readily. A well that extends underground more than 8 feet should have an inside cross section of at least 12 square feet in the clear. Inside dimensions of 2½ by 6 feet or 3 by 4 feet have generally been used and have been found satisfactory. A smaller cross section, however, will serve if the well box is shallow or if it is attached to the side of a cliff (Pl. V, *B*), when several entrances between high and low water should be provided.

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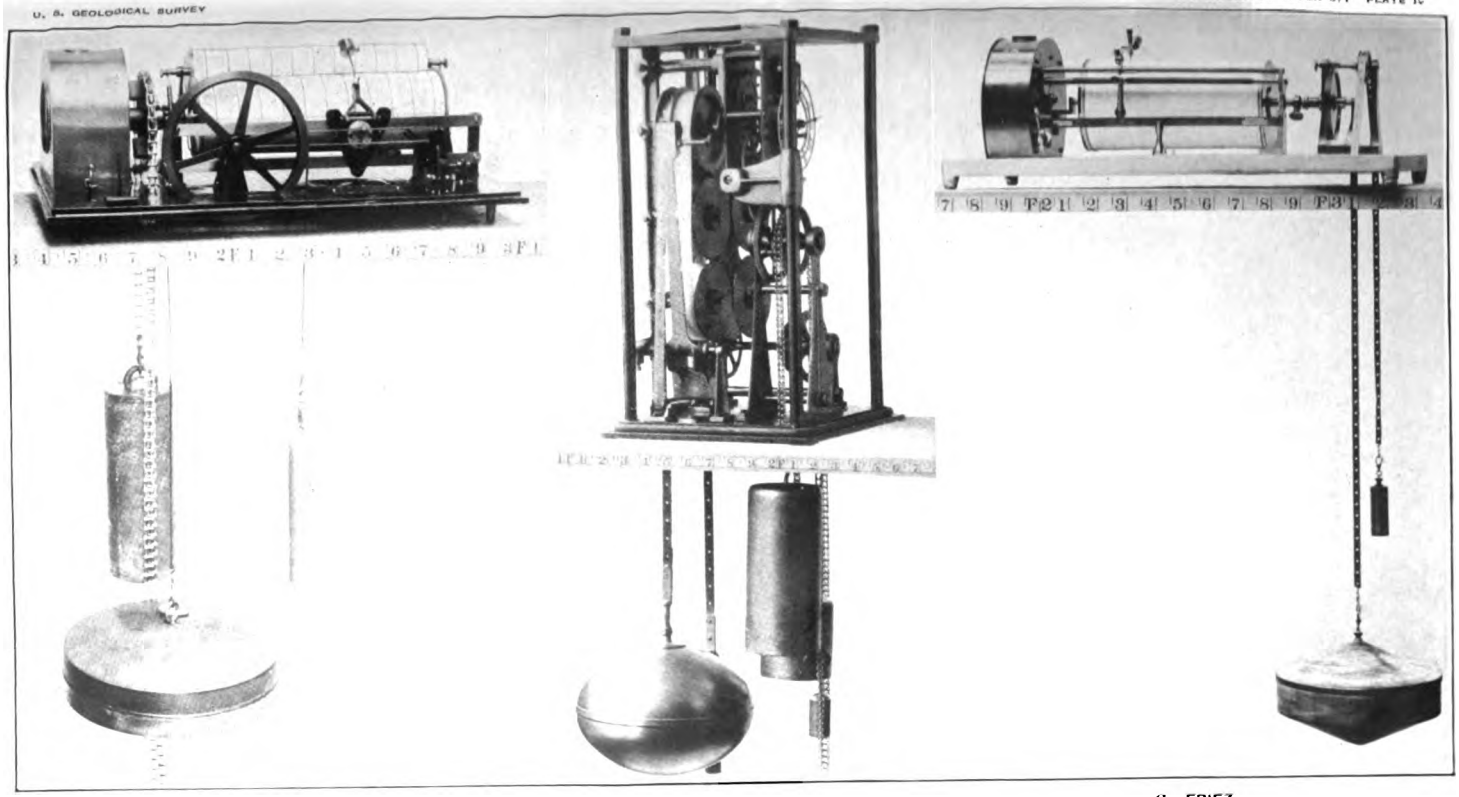

A. STEVENS. *B.* GURLEY. *C.* FRIEZ.

TYPICAL AUTOMATIC RECORDING GAGES.

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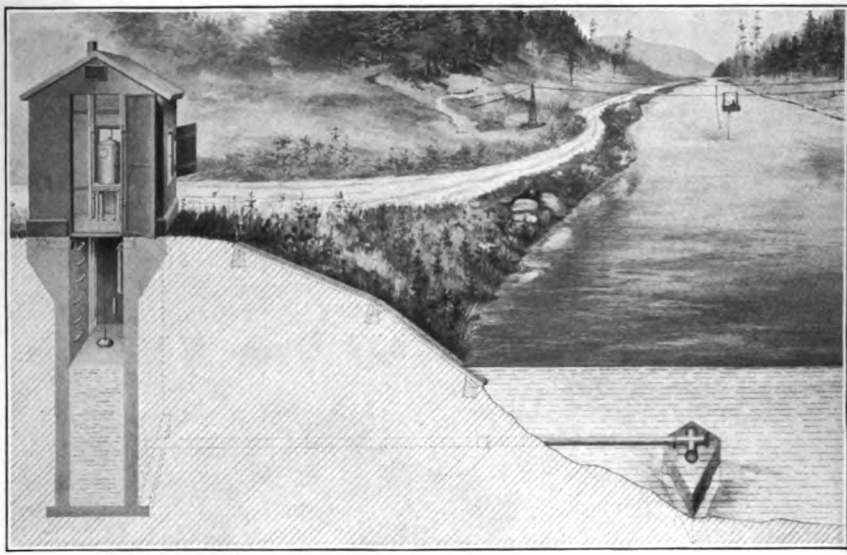
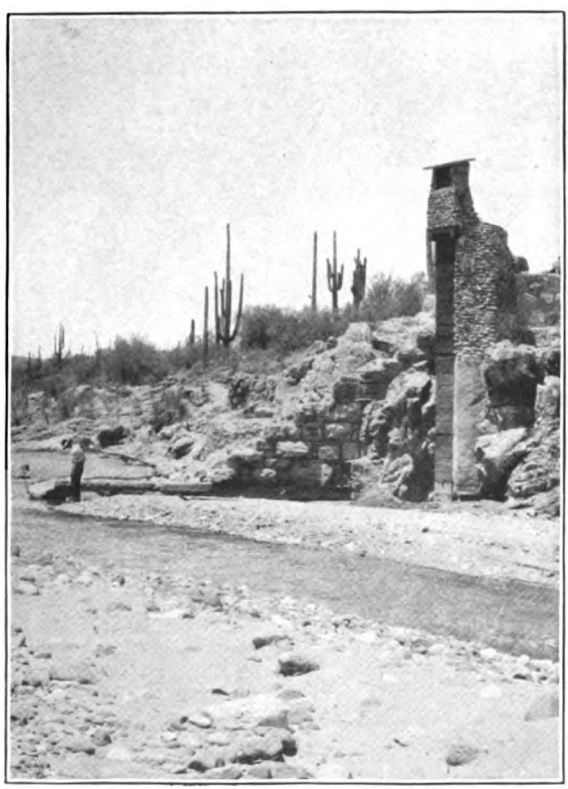


A. TYPICAL GAGING STATION, WITH AUTOMATIC GAGE.



B. WELL WITH NO INTAKE AND WITH SHELTER OF BOX TYPE.

Agua Fria River at Glendale, Ariz.

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The material suitable for lining the wells includes timber (usually treated with a wood preservative), brick, vitrified-tile pipe, concrete, plain or reinforced in mass, concrete rings, stone, cast-iron pipe, and galvanized wrought-iron culvert pipe. The general choice of the material to be used at any station depends on the probable length of the useful life of the station, more durable material being required at stations of expected long usefulness. The specific choice will depend on the accessibility of the station and the availability of labor and material.

To fulfill its purpose of providing a free connection between the stream and the well, the intake should be placed in such position on the stream bed that it will always be covered by water.

For the ordinary station galvanized wrought-iron pipe makes the best intake and under usual conditions will last 10 or 15 years. For stations to be maintained permanently cast-iron pipe, which may be expected to last 40 or 50 years, makes the most durable and substantial intake. Two, three, or four inch pipe has been used, but 4-inch pipe is preferable for ordinary conditions; for heavy silting streams 10 or 12 inch corrugated iron pipe has been found advantageous. Intakes could also be built of vitrified tile, of spiral-riveted corrugated wrought-iron, or of universal or steel-banded wooden pipe.

If cast-iron intake pipe is used, the joints, which are under no great pressure, may be made tight by casting a strip of lead a quarter of an inch thick, an inch wide, and equal in length to the circumference of the pipe, and then driving it home cold with a calking tool. Intakes laid under water also may be sufficiently well calked by this method.

METHODS OF CONSTRUCTION.

TIMBER-LINED WELLS.

Excavations for well and intake are commonly made in one operation by the open-trench method, the material being dug out in benches and shoveled into wheelbarrows, which are then run out toward the stream and dumped. Shoring is put in wherever there is any possibility of caving, and as the excavation approaches the water surface the stream is kept out of the trench by a plank cut-off put at the river end, supplemented, if necessary, by sand bags and clay. The excavation must be carried down below lowest water, so that the intake will always be submerged. The well having been dug, the bottom should be leveled and prepared to receive the floor of the well box.

Plans for a timber well box, 2½ by 5 feet inside dimension, are shown in Plate VI. Its longest cross-sectional dimension should be placed in the direction of the intake pipe. The sides are built of planks (*T*1 *T*2 *T*3, Pl. VI) at least 2 inches thick, spiked to the

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frames *W* and *V*. The bottom *X* is of similar material. Th of the well lining should be tied in by the collars *F J*. The *F J N* should be set level and flush with the top of the lining : elevation of the bottom of the floor, which should be a few i above the ground surface to facilitate drainage. The piece *F* s be placed across the end of the well just below the pieces *J*. 2 by 6 inch supports should be spiked or bolted below the piec but along the sides of the well. The pieces mentioned, together the sills *G*, placed on top of and at the ends of *F*, carry the sh which is bolted to them. It is essential that the floor of the bui carrying the gage table should be rigidly attached to the well li

A ladder with side pieces of 2 by 4 inch material (*S*2) and 2 inch rungs (*S*3) should be spiked to the inside of the lining arranged as shown, to give easy access to the hook gage and bot of the well. The hook gage should be placed on the bed piece *l* as to be in the light entering the well from the trapdoor.

The timber used in the well should be treated with a preservat A list of material for this timber well is given in Table 5.

TABLE 5.—*Bill of material for standard timber well box.*

[Lettered items refer to Plate VI.]

LUMBER, ROUGH.

Item 1. Four pieces 2 by 4 inches by 14 feet (36 feet b. m.), from which cut—
- Two pieces *F*, sills, 5 feet long.
- Two pieces *G*, sills, 6 feet long.
- Two pieces *N*, top frame inside, 2 feet long.
- Two pieces *N*1, top frame inside, 5 feet long.
- Two pieces *J*, top collar outside, 6 feet long.

2. Four pieces 2 by 6 inches by 12 feet (48 feet b. m.), from which cut—
- Two pieces *S*, supports, 6 feet long.
- Six pieces *X*, floor of well.

3. Six pieces 2 by 6 inches by 10 feet (60 feet b. m.), from which cut floor boar and trapdoor.
4. Twenty-six pieces 2 by 6 inches by depth of well, being—
- Twenty pieces *T*1, sides.
- Six pieces *T*2, ends.

5. Four pieces *T*3, ends, 2 by 8 inches by depth of well.
6. —— pieces 4 by 4 inches by 14 feet, from which cut—
- —— pieces *V*, braces, 5 feet long.
- —— pieces *W*, braces, 2 feet long.

7. —— pieces 2 by 4 inches by depth of well, from which cut—
- —— pieces *S*2, ladder poles.
- —— pieces *S*3, ladder rungs.

NOTE.—The cutting scheme shown in the table should be followed carefully. It is customary in construction work in the field to make a reasonable increase in bills of lumber to allow for cuts, undersized pieces, and mistakes.

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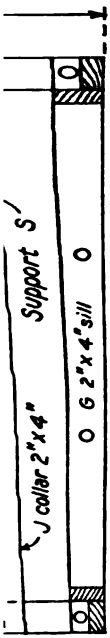

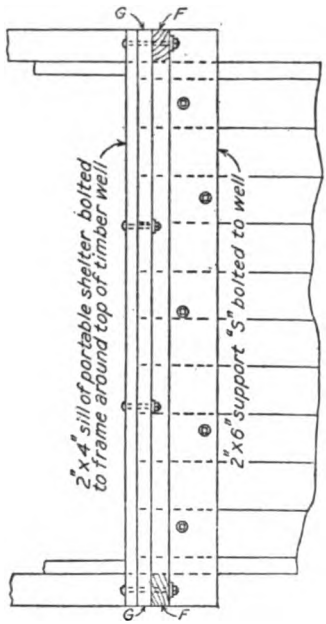

PART SIDE ELEVATION

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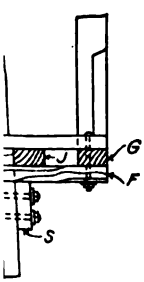

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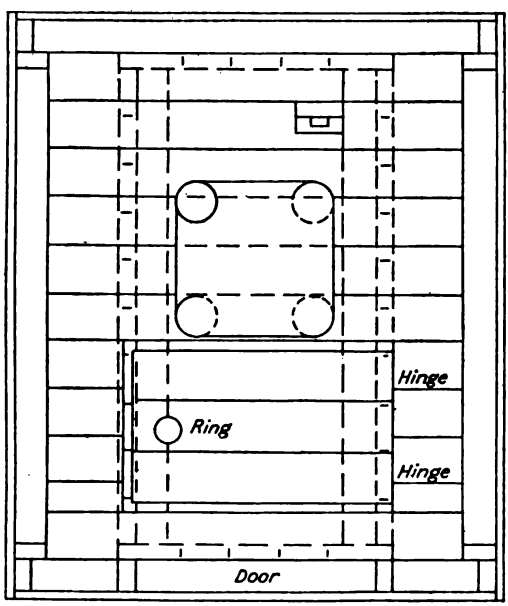

FLOOR PLAN

BLE SHELTER TO STANDARD WELL

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HARDWARE.

Item 8. Hinges and lifting ring for trap door.
9. —— pounds 4½-inch wire nails (30d.).
10. —— pounds 4-inch wire nails (20d.).
11. Intake pipe, anchor, etc.
12. One standard gage table (Table 15, p. 38).
13. One standard hook-gage outfit (Table 1, p. 9).

The floor of the timber well box is placed in position first, with the lower braces *V W* nailed to it, either before or after the floor is put in place. Then the sides, which have been built in separate sections, spiked to the proper cross braces, with the opening for the intake pipe ready, are lowered into their proper positions and all are fastened together. The outside joints of all timber well boxes should be battened to prevent silting. To keep out very fine silt it is desirable to place battens inside as well as outside.

In some places it is advantageous to have the well box built and treated with preservative at a carpenter shop and then hauled to the work, although shallow well boxes may be built on the bank and then lowered into the excavation in one piece. In lowering the well box a set of temporary shear legs, rigged with a tackle, should be used.

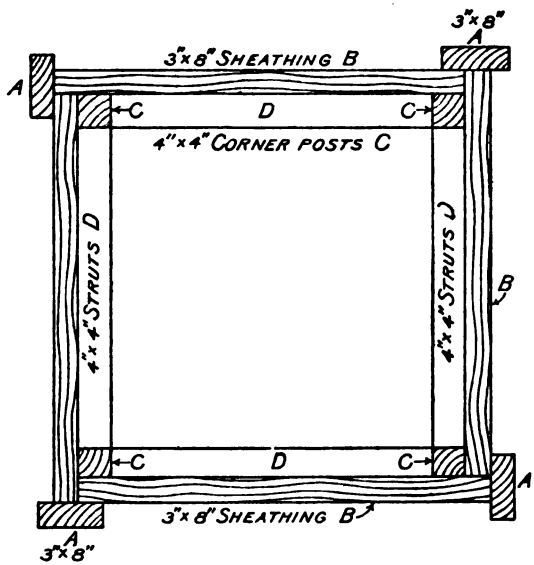

FIGURE 3.—Method of sinking and shoring a well.

If the ground contains no bowlders, a timber well box may be built by the well-known open-crib foundation process. By this process the sides of the well are built in sections about 6 feet long and securely fastened together. A hole 2 or 3 feet deep is dug at the site selected and a section of the well lining is placed vertically in the hole. The material is then excavated from within the well, the lining sinking and new sections being added as the excavation progresses. Care must be taken to keep the structure plumb. This method obviates the necessity of shoring. The floor is placed at the proper depth, and the intake is built by the open-trench method.

A successful method of putting down a well box and at the same time providing adequate shoring is illustrated in figure 3. The excavation is started in the ordinary manner and the corner posts *A* are

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driven in such a relation to each other that the sheathing pieces *B* will form the lining of the completed well box. One end of each piece *B* abuts against post *A*, and is toenailed; the other end rests on the opposite post *A*, and is spiked to it. As the excavation progresses sheathing is added at the bottom until the well is of the desired depth, when corner pieces *C* are inserted to finish the well box. If more than one section is required to attain the requisite depth, the

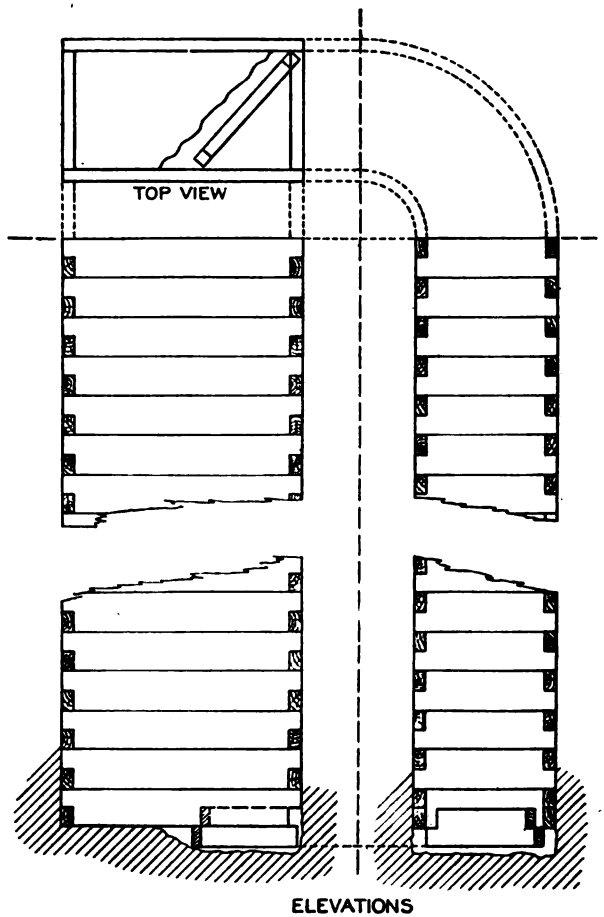

FIGURE 3.—Method of sinking and shoring a well.

dimensions of the lower section should first be decided upon, and those of each upper section adjusted so as to encompass the section immediately below.

Another feasible method of constructing a timber well in earth, especially in places where it may be desirable to tunnel between the well and the stream, is shown in figure 4. By this method the shoring is applied section by section at the bottom of the well as the excava-

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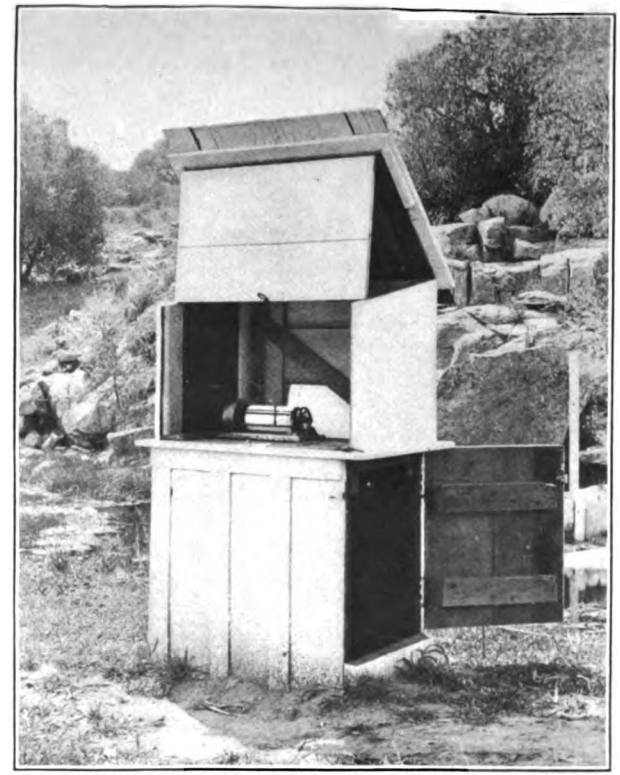
A. WELL IN A ROCK BANK.

Green River at Bridgeport, Utah.



B. CALIFORNIA TYPE OF SHELTER.

San Dieguito River at Bernardo, Cal.

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tion proceeds. The sections used are built of four pieces of plank sawed according to templets in the manner shown (fig. 4). The manner of placing three sides of the planks is evident; the fourth plank is placed by deepening the excavation by the width of half a plank and swinging the plank outward and then upward from below. The sections are held in place by the earth pressure, and the excavation at any stage need never be more than the width of half a plank ahead of the timbering. The vertical alignment is preserved by using a carpenter's level or a plumb bob. The well may be finished by spiking fast corner posts and putting in the middle braces and the usual ladder.

A successful method of constructing a well in a rock bank is shown in Plate VII, *A*.

ANCHORAGE FOR INTAKE PIPE.

In rivers carrying ice, logs, or drift the river end of the intake should be securely fastened to an anchorage to prevent its displacement. Deposits may be avoided by so shaping the anchorage that it will not decrease the velocity of the passing water.

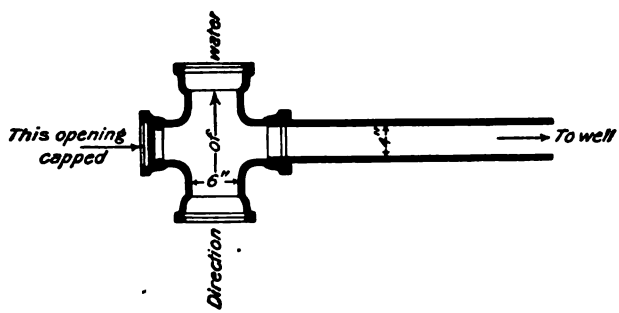

FIGURE 5.—Method of keeping intake clean.

The anchorage may be constructed at times of low water by depositing concrete under water in a simple box form on the stream bottom. No current should be allowed to flow through the form. It may be an advantage to incase quick-setting concrete in paper bags to prevent the cement from washing away.

Where it is necessary to use a cofferdam to install the anchorage the work should be done at favorable stages of the stream and completed as rapidly as possible, precautions being taken against a sudden rise. It is usually economical to provide a power pump at the beginning for removing the water from the cofferdam during construction.

In streams carrying silt, drift, or manufacturing wastes the end of the intake may be made to a certain extent self-cleansing by the method indicated in figures 5 and 6. If the pipe becomes clogged it may be cleaned by means of jointed rods pushed through from the well end, or by a chain drawn back and forth, or by a water jet. The

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river end of the intake pipe should be fitted with a T or cross the anchorage, as shown in Plate V, *A* (p. 15), and in Plate VIII, with a screen to prevent the entry of fish, and the well end should l a valve or other means of closing the intake.

PLAIN AND REINFORCED CONCRETE WELLS.

Plain concrete is suitable for wells of moderate depth set well b in the bank. The plan on Plate VIII brings the length of the ho along the line of the trench for the intake pipe, the width of the ho being such that it can be built in practically the width of the tren This design also allows room for the use of rods for cleaning the inta.

The well should be built to the surface of the ground to furnish foundation for the shelter. The walls of the well should be of

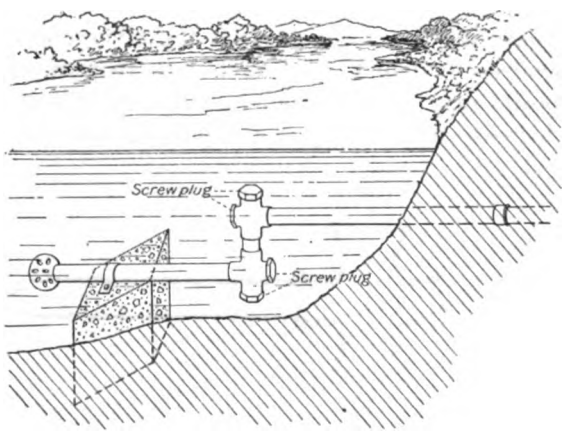

FIGURE 6.—Method of keeping intake clean.

proper thickness for the depth, due consideration being given to the nature of the material passed through. Three feet from the top of the well the sides should be corbeled out to the dimensions shown on the plan. In localities where the ground freezes to a great depth it may be advisable to begin corbeling at a greater distance below the frost line. If used with a standard timber shelter, the well should be finished to the dimensions shown in Plate IX, top view of well, and the necessary anchor bolts set as indicated.

To construct the plain-concrete well use the material specified in Table 6.

TABLE 6.—*Bill of material for plain-concrete well supporting a standard timber shelter.*

[Lettered items refer to Plate VIII.]

Item 1. 2.7 cubic yards 1-2-4 concrete for upper 3 feet of well, requiring—
17 bags cement.
1¼ yards sand.
2½ yards stone.

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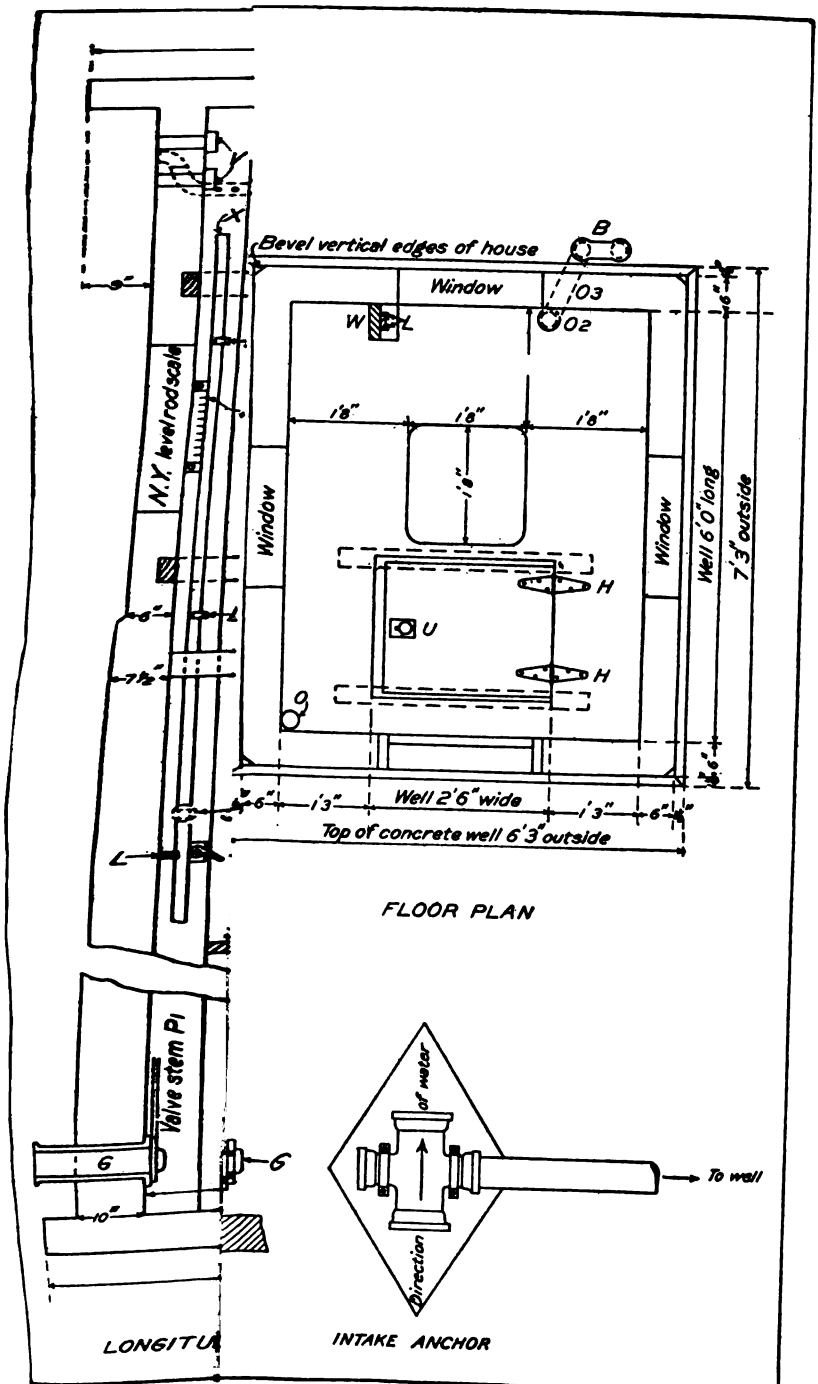

IORAGE.

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Item 2. 0.6 cubic yard (approximately) of 1–2–4 concrete in walls of well for each foot of depth below the first 3 feet. Each cubic yard requires—
6.4 bags cement.
0.45 yard sand.
0.90 yard stone.

3. 1.2 cubic yards 1–3–6 concrete in footing, requiring—
6 bags cement.
5¾ yards sand.
11½ yards stone.

4. —— square feet of wire reinforcement for reinforcing floor.
5. Two pieces light rail *C*, for door rest, each 3½ feet long.
6. One lifting ring *U*, for trap door, with screws.
7. One pair 6-inch strap hinges *H*, with 4-inch stove bolts for all holes.
8. ——pieces *R*, 1-inch iron 3 feet long, for steps, inner edge to set 3 inches from face of wall.
9. ——½-inch bolts *J* with nuts and washers, to hold bed piece to wall.
10. Twelve anchor bolts ½ by 10 inches, with 1 nut and 1 washer to fasten shelter to well.
11. One gallon carbolineum for treating gage rod, table, etc.
12. One piece lumber 2 by 6 inches by 14 feet, for trapdoor *T*.
13. One standard hook-gage outfit (Table 1, p. 9).
14. One standard shelter (Table 9, p. 26).
15. One standard gage table (Table 15, p. 38).

NOTE.—The separate items for the forms may be taken from Table 13 (p. 33).

The reinforced-concrete well shown in plan in Plate IX is suitable for use in exposed situations, such as is illustrated in Plate X, *A*, where the sides of the well may have to withstand the impact of floating débris. A well of this type may be used also with a standard wooden or metal shelter, in which case the top dimension should be finished as noted on the plan, the necessary anchor bolts being set as indicated.

Under some conditions it may be necessary to provide ventilators for the well, hinges and lifting ring for the trapdoor, intake and valve, a gage table, and a standard hook-gage outfit.

In the construction of the reinforced-concrete well use the items specified in Table 7.

TABLE 7.—*Bill of material for reinforced-concrete well with timber or metal shelter.*

[Lettered items refer to Plate IX.]

Item 1. Three cubic yards 1–2–4 concrete in corbel and footing.

2. Twenty-four cubic feet of 1–2–4 concrete per foot of well between bottom of corbel and top of footing.
(The quantity of cement, sand, and stone per yard of concrete is given in item 2 of Table 6, p. 20.)

3. Twelve anchor bolts ½ by 10 inches with one nut and one washer, to fasten shelter to well. (See Pl. IX.)
4. ——⅜-inch hook bolts with nuts and one washer each to fasten staff gages to well.
5. One trapdoor of wood or sheet iron.
6. Lifting ring and hinges for trapdoor. (See Table 13, p. 33.)

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Item 7. One standard hook-gage outfit (Table 1, p. 9).
8. Intake and valve. (For items see Table 13, p. 33.)
9. One standard gage table (Table 15, p. 38).
10. Carbolineum or other wood preservative for treating gages and gage table.
11. Necessary ventilators.

STEEL REINFORCEMENT.

Item 1. Curved bars *C*1, in footing.
2. Ties *C*2 and *C*3, around corbel.
3. Ties *C*4, around well.
4. Bent bars *B*1, in footing.
5. Bent bars *B*2, in footing.
6. Bent bars *B*3, in corbel.
7. Bent bars *B*4, in footing.
8. Bent bars *B*5, steps in well.
9. Straight bars *S*1 and *S*2, in footing.
10. Straight bars *S*8, in walls of well.

NOTE.—The separate items for the forms may be taken from Table 16 (p. 40).

Neither plain nor reinforced concrete should be used if the waters of the stream are polluted by mining or industrial wastes that would cause it to disintegrate. It is highly essential that the sand and gravel entering into the concrete be clean.

CONCRETE COMBINATION WELL AND SHELTER.

A concrete well adapted to use on streams characterized by low banks and fluctuating little in stage is shown in Plate X, *B*, and in plan in Plate XI. In the upper part of the well, which is carried above the surface of the ground about 3 feet, a gage table 12 inches wide is placed. This table is supported at each end by a 2 by 4 inch batten, to which it is securely fastened. The batten should be bolted to the wall of the well. The opening in front of the gage table is covered by a trapdoor *C*, which serves as an extension to the table, useful in the adjustment of the gage. The cover of the well is made of No. 10 steel plate, so arranged that it may be lifted clear of the well, and is prevented from sliding by two battens *S*, of 2 by 4 inch material riveted to its underside. Two hasps *H*, also riveted to the cover in position to engage corresponding staples placed in the concrete, afford a means of locking on the cover. This construction is fire and bullet proof—an important consideration at some stations. In this type of construction ample ventilation must be provided.

TABLE 8.—*Bill of material for combination concrete well and shelter.*

[Lettered items refer to Plate XI.]

Item 1. One piece lumber 2 by 4 inches by 14 feet, from which cut—
Two pieces *S*, cleats, 3 feet 6 inches long.
Two pieces *D*, sills, 3 feet 6 inches long.
2. Two pieces 1 by 6 inches by 12 feet, T. G. & S., from which make shelf *B* and trapdoor *C*.

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A. REINFORCED-CONCRETE WELL AND SHELTER.
American River at Fairoaks, Cal.

B. CONCRETE WELL AND SHELTER COMBINED.
Muddy River at Moapa, Nev.

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Item 3. Six machine bolts *E*, ½ by 8 inches, with nuts and 2 washers each.
4. Two hasps *H*, riveted to iron cover and 2 staples with shield to go into concrete wall.
5. Two United States Geological Survey standard padlocks.
6. —— pieces 1-inch iron 3 feet long for steps, inner edge to be 3 inches from face of wall.
7. One piece No. 10 steel plate *R*, cover, 4 feet 2 inches by 4 feet 8 inches, with cleats *S* riveted to it.
8. Three dozen F. H. wood screws, 2 inches by No. 10, for shelf and trapdoor.
9. The concrete footing contains 14 cubic feet of concrete.
10. The concrete walls contain 7.5 cubic feet per foot depth of well.
11. One or more intake pipes.
12. Standard hook-gage outfit (Table 1, p. 9).

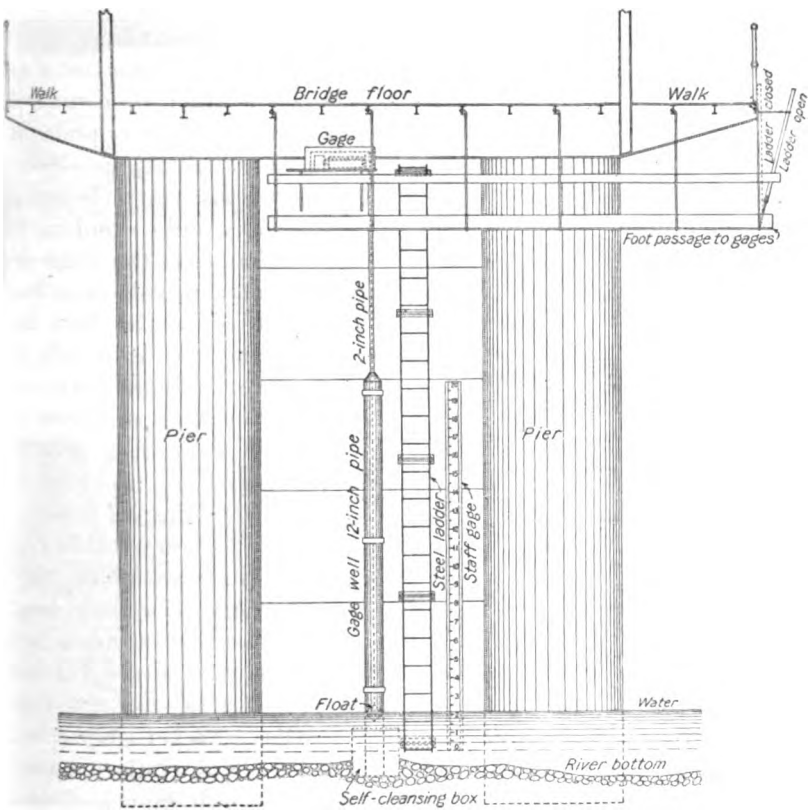

FIGURE 7.—Automatic gage on Cushing bridge piers.

MISCELLANEOUS DESIGNS.

The use of wells of standard design, described and illustrated in the preceding pages, is as a rule desirable, but a number of other types have been designed to take advantage of local conditions. Among these types is the well shown in Plate XII, *A*, and figure 7. This well is made of spiral riveted pipe fastened by steel straps to the web that joins two Cushing cylinders of a bridge pier. From the

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top of the well, which is above extreme high water, a smaller protecting tube for the float tape extends to the hanging platform on which the gage is placed. In installing work of this kind a chain drill is almost a necessity.

In some places cast concrete rings or pipe sections (Pl. XII, *B*), corrugated iron pipe (Pl. XVII, *B*, p. 31), and wood-stave pipe have been used for wells.

PROTECTION FROM FREEZING.

In northern latitudes special precaution must be exercised to guard against the possible interruption of the record by freezing of the water in the well. In selecting one of the several methods available to prevent freezing, first cost and probable cost of operation must be considered. The most effective protection against freezing is obtained by placing the well back in the bank and so building the well box that the water surface in the well is at least 2 feet below the frost line. This method is usually expensive. Where such construction does not seem advisable freezing may be prevented by applying an oil cover, using oil to a depth equal to the probable maximum thickness of ice, plus 2 feet. A device for reducing the quantity of oil required is shown in figure 8. An exposed well may be protected from freezing by building a jacket around it 8 feet above the water surface, leaving between the well box and the jacket a space of 2 feet, which is filled with manure, leaves, or some similar material. Where no other method seems feasible the well may be heated. At stations near a suitable electric circuit a 100-watt carbon light may be burned continuously in the well. An oil heater that may be used for heating the well is prepared by soldering near the top of a 14-quart iron kettle a circular tin plate into which is also soldered a lamp burner, on which a tin or mica chimney is used (fig. 9). The oil chamber holds 2 gallons, sufficient for three days' burning. The kettle heater is counterweighted, so that it will rise and fall with the water in the well. In extremely cold weather more than one such heater may be required.

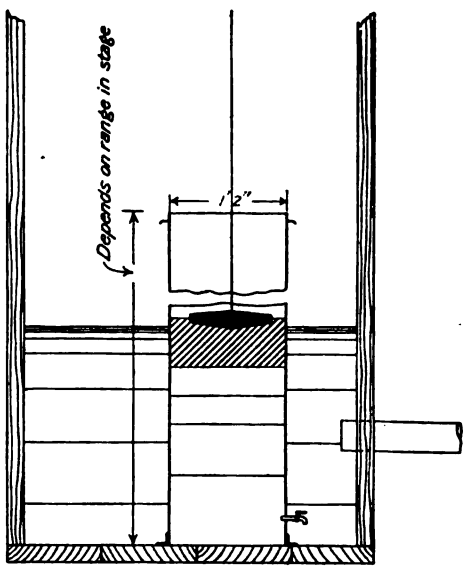

FIGURE 8.—Oil pipe for float, to prevent freezing.

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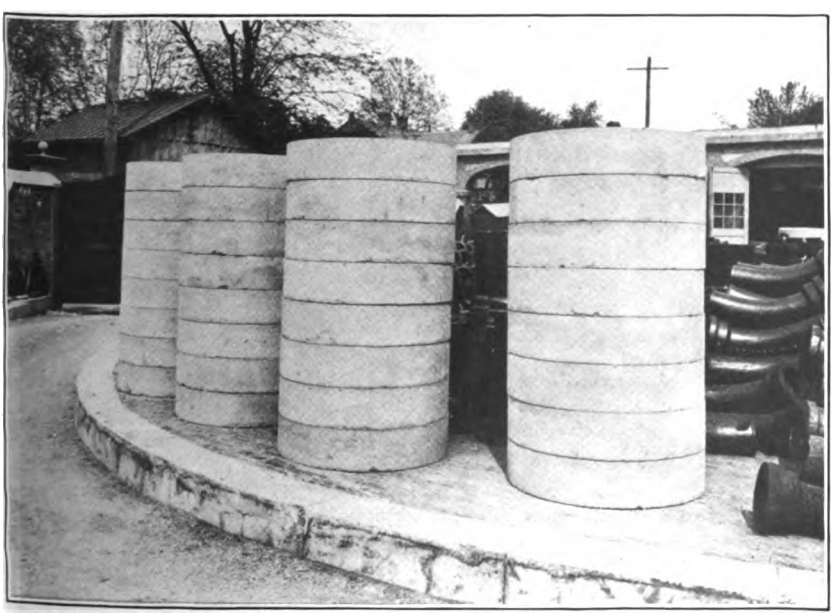
A. GAGES ON WEB OF CUSHING BRIDGE PIERS.

Chippewa River at Chippewa Falls, Wis.



B. CAST CONCRETE RINGS.

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SHELTERS.

TYPES AVAILABLE.

The type of shelter to be used at any station is determined by considering the three elements—utility, safety, and appearance—the weight given to each varying with the location of the station. The types of shelters here illustrated and described are adapted to a wide variety of conditions, and each has proved satisfactory in its own field.

If a station is to be operated all year round the shelter must be large enough to allow the observer to go inside during inclement weather and to pass conveniently around the gage table while inspecting and adjusting the gage. Such shelters are shown in Plates IX (p. 20), XIII (p. 26), and XIX (p. 34).

In the arid regions, where rain is not likely to interfere with the inspection and adjustment of the gage, especially at stations operated during warm weather only, shelters of the types shown in Plates XV and XVI, *B* (pp. 28, 30) have proved satisfactory. These shelters may be used on any of the standard wells. The combination shelter and well shown in Plate XIV (p. 28) should be used only on shallow wells (Pl. VII, *B*, p. 18).

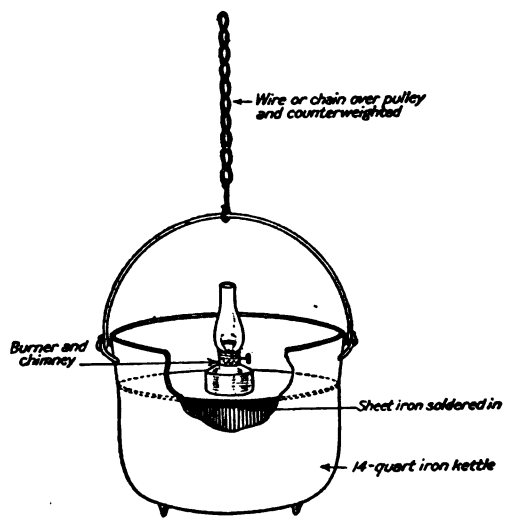

FIGURE 9.—Floating oil heater, to prevent freezing.

SECTIONAL WOODEN SHELTERS.

The shelter shown in Plate XIII and Plate XVI, *A*, is built in five sections, one roof section and four side sections, not too large to be carried on a wagon. The siding may be of car-siding, of tongued-and-grooved or of ship-lap lumber, with or without clapboards or shingles. If additional protection is required, the interior may be ceiled. The corner posts *A* and *B*, the sills *C* and *D*, and the plates *P*2, together with the other posts and braces, are cut and spiked together, as shown in detail on the drawing. The siding is nailed to the separate frames, which are then bolted together, as indicated. The roof boards are nailed to the rafters in the proper position and are covered with roofing paper. The roof is then lifted into place and bolted to the side walls. The shelter is bolted to the top of the well, as shown in

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Plate XIII or Plate XXIV, *B* (p. 40). Windows may be p on each side and one in the rear of the building. Stock sa six lights of 8 by 10 inch glass are placed on the frames held in place by cupboard buttons, screwed to the frame sashes are flush with the inside faces of the frames *E* and window is protected by a wooden shutter, which is fasten inside by a screw hook and eye. A door, provided with has and lock, should be made to suit the style of shelter. For shelter ceiled inside and with siding outside, a standard frame, as shown on the plans for concrete shelter, may be

The floor should be of 2-inch plank securely spiked to the s constructing the trapdoor through which entrance is had to ample allowance should be made for swelling, say an inch e and at the end. The bed piece for the hook gage should be to the frame of the well and to a horizontal piece of 2 by 6 inc rial 5 feet long, fastened to the top of the frames *E*. To the b standard lugs should be attached on each side of the hook-ga spaced about 3 feet apart. Opposite the standard scale a sa should be provided to hold the gage at any desired position.

Where the change of stage is considerable it may be necess allow the hook gage to pass through the roof by using a small tr or the same device as for concrete shelters.

The shelters should be kept well painted or should be treated carbolineum. A bill of material and cutting scheme for timber ters is given in Table 9.

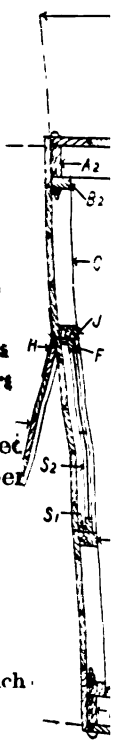

TABLE 9.—*Bill of material for standard wooden shelter.*

[Lettered items refer to Plate XIII.]

LUMBER.

Item 1. Four pieces 2 by 4 inches by 12 feet (32 feet b. m.), S 4 S, from which
Two pieces *A*2, posts, 5 feet 10 inches long.
Two pieces *B*2, posts, 5 feet 10 inches long.
Two pieces *C*, sills, 5 feet 4 inches long.
One piece *M*, lintel, 2 feet 6 inches long.
Four pieces *P*1, braces, 1 foot long.
One piece *R*5, rafter, 2 by 3 inches by 5 feet long.

2. Twelve pieces 2 by 4 inches by 10 feet (80 feet b. m.), S 4 S, from which cu
Two pieces *A*1, sills, 7 feet long.
Two pieces *B*1, sills, 7 feet long.
Two pieces *D*, sills, 5 feet long.
Four pieces *E*, sills, 5 feet long.
Two pieces *G*, door jambs, 7 feet long.
Six pieces *J*, window jambs, 2 feet 4 inches long.
Two pieces *P*, sills, 4 feet 8 inches long.
Two pieces *P*2, plates, 5 feet long.
Two pieces *R*3, rafters, 5 feet long.

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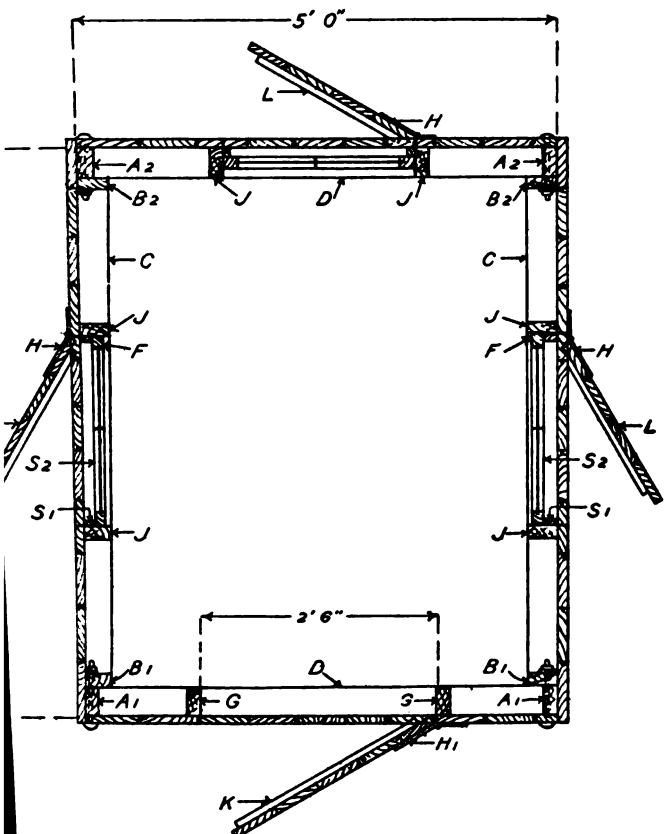

SECTIONAL PLAN

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Item 3. Four pieces 1 by 4 inches by 12 feet (16 feet b. m.), S 4 S, from which cut—
Two pieces *V*1, battens, 5 feet 2 inches long.
Two pieces *V*2, battens, 6 feet 4 inches long.
—— battens on window shutters.

4. 1-inch boards for roof to be 7 feet long and sufficient in number to cover 6 feet of width (42 square feet net).
5. Boards on each side to cover 6 feet 2 inches of width and to be of proper height (87 square feet net).
6. Boards on rear 6 feet 4 inches long, to cover a length of 5 feet 0 inches (32 square feet net).
7. Boards on front 7 feet 7 inches long, to cover 5 feet of width—less doorway when stock door is used (34 square feet net).
8. Three window sashes *F*, each with 6 lights, 8 by 10 glass.
9. One stock door, 2 feet 6 inches by 6 feet 6 inches, with dead lock and hinges ready to hang.

NOTE.—The cutting scheme should be followed carefully. It is customary in construction work in the field to make a reasonable increase in bills of lumber to allow for cuts, undersized pieces, and mistakes.

HARDWARE.

Item 10. Three pairs 6-inch T hinges *H*.
11. One pair 10-inch T hinges *H*1.
12. Six door buttons, 2 inches, to secure window sashes (Sargent & Co., No. 10).
13. Four carriage bolts ⅜ by 4½ inches, *Z*1, with one washer each.
14. Eight carriage bolts ⅜ by 7 inches, *Z*2, with one washer each.
15. One safety hasp with staples and screws.
16. One United States Geological Survey padlock.
17. Five pounds 20d. (4-inch) nails.
18. Ten pounds 8d. (2½-inch) nails.
19. One-half gross No. 10, 1½-inch F. H. bright wood screws to fasten battens to window shutters.
20. Four screw hooks and eyes for window shutters and door.
21. —— waterproof roofing to cover 42 square feet net.
22. Four pounds No. 8 large-head barbed roofing nails.
23. Two gallons gray mixed paint.

CALIFORNIA SHELTER.

This type of wooden shelter (Pl. VII, *B*, p. 18) is only large enough to contain the gage. Because of its low cost it is adapted to use on small streams and canals or for temporary purposes. When so used it may be mounted on the special well shown in Plate XIV if the well is shallow. The shelter consists of a base *G*, of 2-inch material, across which is laid a smooth floor, 1 inch thick, of tongued-and-grooved material. The sides *A* and the back *B* closely surround this floor and rise above it to the dimensions shown on the drawing. The sides and back are securely nailed to each other and to the floor *F*, as well as to the corner posts and battens *D* and *E*. The roof *R* is hinged at the back, and the front is also fastened by hinges to the roof, the shelter being opened as shown on the drawing. The roof of this shelter is ordinarily covered with No. 24-gage galvanized iron. The structure should be kept well painted. A bill of material is given in Table 10.

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TABLE 10.—*Bill of material for California-type well and shelter.*

[Lettered items refer to Plate XIV.]

LUMBER.

Item 1. Six pieces 1 by 6 inches by 14 feet (42 feet b. m.), T. G. & S., from which c
Six pieces *F*, gage table, 2 feet 2 inches long.
Six pieces *G*, well cover, 3 feet 4 inches long.
One piece *J*, batten, 1 by 2 inches by 3 feet 2 inches long.
One piece *J*1, batten, 1 by 2 inches by 3 feet 4 inches long.
Two pieces *L*, battens, 1 by 2 inches by 2 feet 4 inches long.
Two pieces *M*, battens, 1 by 3 inches by 1 foot 4 inches long.
One piece *M*1, batten, 1 by 3 inches by 3 feet long.
Two pieces *N*, battens, 1 by 3 inches by 2 feet 6 inches long.
Six pieces *R*, roof sheathing, 3 feet 6 inches long.

2. Four pieces 1 by 8 inches by 12 feet (32 feet b. m.), T. G. & S., from whi cut—
Six pieces *A*, sides of shelter, 2 feet 4 inches long.
Six pieces *B*, back and front of shelter, 2 feet 8 inches long.
Two pieces *C*, battens, 1 by 4 inches by 1 foot 5 inches long.
Two pieces *E*, corner braces, 1 by 4 inches by 1 foot 8 inches long.
Two pieces *K*, battens, 1 by 4 inches by 1 foot 10 inches long.
Three pieces *S*, door to well, 2 feet 2 inches long.

3. One piece 2 by 4 inches by 2 feet, S 4 S, from which cut 2 pieces *D*, corne braces, 2 by 2 inches by 2 feet long.
4. —— pieces *O*, well frame, 2 by 4 inches by 2 feet long.
5. Two pieces *P*1, well frame, 2 by 4 inches by 2 feet 6 inches.
6. —— pieces *P*, well frame, 2 by 4 inches by 2 feet 4 inches.
7. Two pieces *Q*, door battens, 1 by 4 inches by 1 foot 11 inches.
8. Four pieces *T*1, side of well, 2 by 6 inches by depth from surface of ground to bottom of well plus 6 inches.
9. Four pieces *T*2, side of well, 2 by 6 inches by depth from surface of ground to bottom of well plus 3 feet.
10. Twelve pieces *U*, back and front of well, 2 by 6 inches by depth from surface of ground to bottom of well plus 3 feet.
11. Six pieces *V*, bottom of well, 2 by 6 inches by 2 feet 4 inches.
12. —— pieces *X*, ladder rounds, 1 by 4 inches by 2 feet.
13. Two pieces *Y*, ladder poles, 2 by 4 inches by depth of well.
14. One piece *Z*, batten, 2 by 4 inches by 2 feet 4 inches S 4 S.

HARDWARE.

Item 15. One pair 3-inch butt hinges *H*, with screws.
16. One pair 5-inch T hinges *H*3, with screws.
17. One safety hasp, 6 inches, *H*1, with screws.
18. One safety hasp, 6 inches, *H*2, with screws.
19. One pair strap hinges, 6 inches, *T*, with screws.
20. Two pounds 4½-inch wire nails (30d.).
21. Eight pounds 4-inch wire nails (20d.).
22. Five pounds 2½-inch wire nails (8d.).
23. Two pounds 2-inch wire nails (6d.).
24. —— gray mixed paint.
25. One sheet No. 24 galvanized iron, 36 inches by 45 inches, to cover roof.
26. Intake pipe, fittings, anchor, etc., as required.

NOTE.—This bill of material is based on special well shown in Plate XIV. The cutting scheme shown above should be followed carefully. It is customary in construction work in the field to make a reasonable increase in bills of lumber to allow for cuts, undersized pieces, and mistakes.

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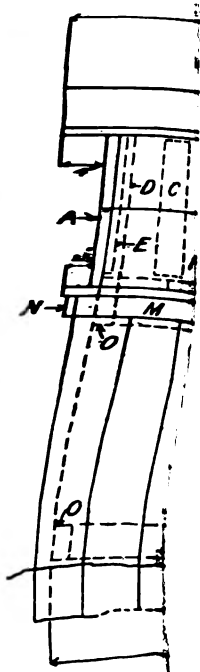
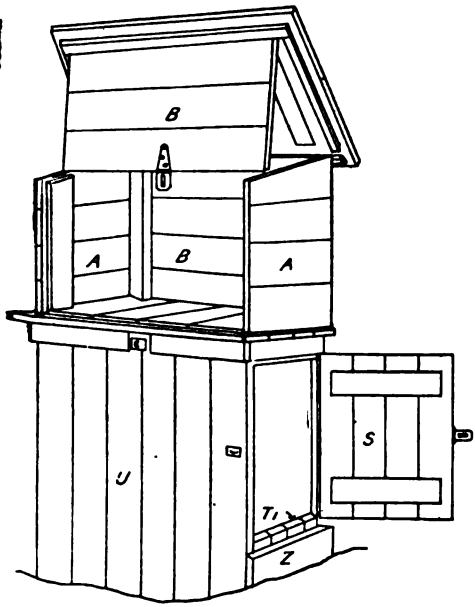
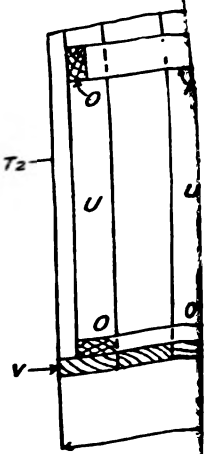


FRONT





SECTIONAL

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BOX SHELTER.

A very simple and inexpensive shelter is shown in Plate XV. This type has been found useful in the arid regions in situations similar to those shown in Plate V, *B* (p. 15).

The shelter is made of 2-inch material, the sides *A* being dovetailed into the back and front *B*, the corners being bound with galvanized sheet iron and the top covered with the same material or roofing paper. The box is separated by a tongued-and-grooved joint into upper and lower parts, the tongue being on the pieces *A*2—*B*2, and the groove being on the upper part. The lower part, or base, is fastened to the top covering of the well by 2½-inch screws, countersunk into the pieces *A*2—*B*2. Hinges *H* allow the cover to be turned back when inspecting the gage. If a gage of unusual dimensions is used, care must be taken to adjust the size of the box accordingly.

These shelters are made to best advantage in a woodworking mill. The parts may be crated and shipped into the field to be nailed together. They should be painted before being shipped. A bill of material is given in Table 11.

TABLE 11.—*Bill of material for box-type shelter.*

[Lettered items refer to Plate XV.]

LUMBER.

Item 1. One piece 1 by 6 inches by 14 feet (7 feet b. m.), T. G. & S., from which cut 6 roof boards *R*, 1 foot 11 inches long.

2. Two pieces 2 by 6 inches by 10 feet (20 feet b. m.), T. G. & S., from which cut—
   - Four pieces *A*1, ends, 1 foot 5 inches long.
   - Two pieces *A*2, ends, 2 by 3 inches by 1 foot 5 inches long.
   - Two pieces *B*1, front, 2 feet 4 inches long.
   - Two pieces *B*3, back, 2 feet 4 inches long.
   - Two pieces *B*2, front and back, 2 feet 4 inches long.

3. Three pieces lath, *C* and *D*, for binding edge of roofing.

4. Covering for roof. May be tar paper or No. 24 galvanized iron 24 by 36 inches.

HARDWARE.

Item 5. One piece No. 27 galvanized sheet iron, 30 inches wide by 11 inches long, from which cut—
   - Two pieces *G*1, 6 inches wide by 11 inches long.
   - Two pieces *G*3, 6 inches wide by 9½ inches long.
   - Four pieces *G*2, 2½ inches wide by 6 inches long.

6. One pair 3-inch butt hinges *H*, with screws.

7. One safety hasp *L*, 6 inches, with screws.

8. One United States Geological Survey standard padlock.

9. Two screw hooks and eyes *K*.

10. Six wood screws, F. H., bright, *S*, fastening shelter to deck over well.

11. Two pounds 20d. (4-inch) wire nails.

12. One pound 1½-inch No. 6 gage wire nails to fasten corner plates.

13. One quart gray mixed paint.

NOTE.—The items above do not include the deck over the well.

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PORTABLE SHELTER.

A shelter that has been found useful in preliminary studies with automatic gages is shown in Plate XVII, *A*.

The structure shown in plan in Plate XVIII consists of four standards of ¾-inch galvanized pipe, which are driven into the bed of the stream at a favorable site and to which is clamped the deck *D*. For convenience in transportation the pipe is cut into 2-foot sections, which are joined in the field by pipe couplings. The threads on the pipe should be cut long enough to permit the ends of the pipe to touch within the couplings when screwed up. A cap is placed on the top section to serve as a drivehead when the pipe is driven in. Wire loops are slipped over the pipe standards to prevent them from spreading as they are driven. After the pipes have been driven far enough into the stream bed to hold firmly, the deck is fitted on the standards, is made level, and is clamped in place. Hexagon nuts on the bolts and an S wrench add to the ease with which the deck may be set. The holes in the clamps *C* may advantageously be slotted. The slots should be 1 inch long to allow for adjustment.

The deck having been fastened in place, the galvanized side plates are next put on. These plates are cut from a stock sheet 36 inches wide and 96 inches long. The positions of all the holes should be carefully laid out on one plate, which is then drilled with holes just large enough to admit the end of the center punch. This plate is then retained as a templet, from which all other side plates are duplicated. The side plates are kept from bending by wooden stiffeners, ½ by 1 inch in cross section and 18 inches long, with round-head stove bolts, ¼ by 1 inch, with a washer under the head and next the wood.

The side plates are joined together and fastened to the standards by stove bolts, $\frac{3}{16}$ inch by 4 inches, which may be bent readily in a vise, around a short piece of ¾-inch pipe. The heads of the bolts are sawed off and the ends threaded with a die (thread 10 by 24) held in a clamp that can be used in a bit stock.

For convenience in shipment the side plates, stripped of stiffeners, are placed between the sills *E;* and the deck, with plates, bolts, and all tools, are packed in the canvas cover. The pieces of pipe are tied together and shipped as a separate parcel.

Stove bolts, wing nuts, and washers should be bought by the box and prepared for use by the engineer before he goes into the field.

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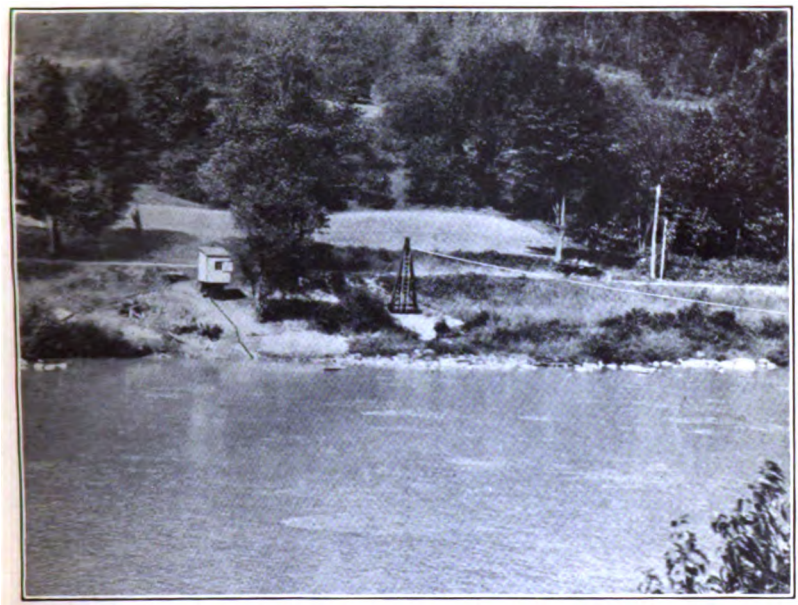
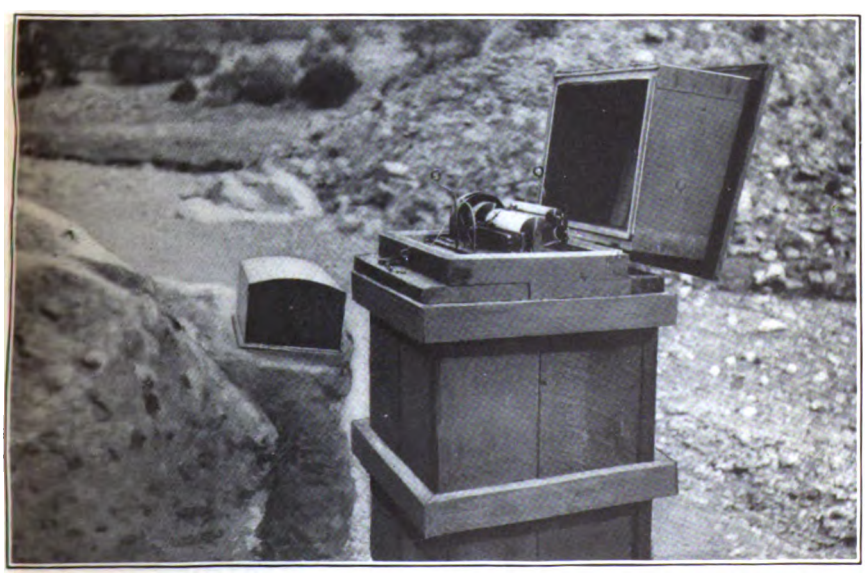


A. STANDARD WOODEN SHELTER.

Deerfield River at Charlemont, Mass.



B. WOODEN-BOX SHELTER.

Arroyo Hondo at Santa Fe, N. Mex.

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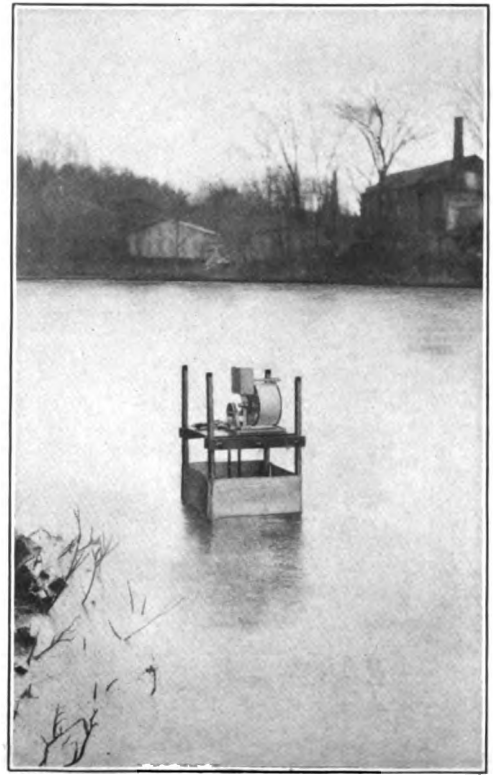
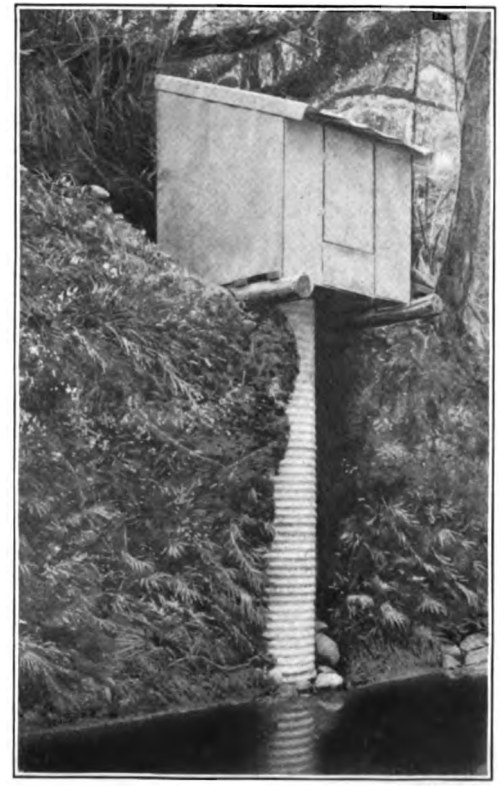


A. PORTABLE GAGE SHELTER.



B. SPECIAL HAWAIIAN SHELTER.

North Branch of Ka

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TABLE 12.—*Bill of material for portable shelter.*

[Lettered items refer to Plate XVIII.]

LUMBER.

Item 1. Two hardwood clamps *C*, 1 by 2 by 19 inches long.
2. Six pieces hardwood F, ½ by 3 by 18 inches long, for deck *D*.
3. Two hardwood sills *E*, 1 by 2 by 19 inches long.
4. Four wooden stiffeners, ¼ by 1 by 18 inches long, for each section of plates.
5. Canvas cover of 18-ounce brown duck, 19 by 21 inches, height depending on kind of gage used, with holes for hasp staples, the openings protected with thin galvanized plates riveted to the canvas.

HARDWARE.

Item 6. —— sections, each 4 pieces, of ¾-inch heavy galvanized wrought-iron pipe *P*.
7. Four couplings, ¾-inch, galvanized, for each section of pipe.
8. Four caps, ¾-inch, heavy, galvanized, for top section.
9. Four plates, 13½ by 18 inches, of No. 24 galvanized iron, with ¼-inch holes placed as shown on drawing.
10. Two hasp staples *H*, with screws, for fastening canvas cover.
11. Four carriage bolts *A*, ½ inch by 4½ inches, with one washer and one hex nut.
12. Eight stove bolts, $\frac{3}{16}$ inch by 4 inches, with 16 washers ¼-inch and 16 wing nuts $\frac{3}{16}$ inch, for each section of plates.
13. —— R. H. stove bolts, ¼ by ¾ inch, for fastening sections together and for fastening on stiffeners, with ¼-inch washers.
14. Two United States Geological Survey standard padlocks.
15. Two 8-inch Stillson wrenches.
16. One S wrench to fit nuts on ½-inch bolts.
17. One screw driver.
18. Four brass stove bolts to fasten gage to deck.
19. Three-fourths inch F. H. bright wood screws, for fastening deck to sills *E*.

PLAIN-CONCRETE SHELTER.

The arrangement of the concrete shelter is clearly shown on *Plate* V, *A* (p. 15). It should be noted, however, that in order to show the greatest number of details in the cut, the longer axes of the house and well have been turned parallel to the stream. As actually constructed the longer dimension of the well is placed at right angles to the stream and the shorter dimension parallel to the stream.

The dimensions in plan (Pl. VIII, p. 20) give ample but not excessive room inside the shelter to allow the gage to be inspected and adjusted without discomfort. In fact, it is desirable to have a clear passage all around the gage table.

The 2 by 4 inch furring strips placed in the walls afford means for fastening cupboards, etc., or for placing hooks to carry various pieces of minor equipment necessary for the operation of the station. Directly over the center of the door a half-inch eyebolt set into the concrete for carrying a pulley and rope is useful for a number of

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purposes, such as bailing the well. The stirrup to which is faste the bed piece for the rod gage should be set into the concrete attached by means of ¼-inch bolts. Two pieces of 2-inch pipe ventilator should be inserted in the back and front of the wall: the house. Pipe caps should be provided to close these vents. 3-inch ventilator runs through the building in one corner and pa out under the eaves. In cold weather it is desirable in some loc ties to close all vents to prevent the water in the well from freezi

Where the variation in stage is great it may be necessary to lift hook gage so high that the gage rod must pass through the roof. meet this condition a smoke jack of galvanized iron, 6 inches diameter, may be placed directly over the gage rod and set into roof and covered by a close-fitting cap. If necessary for the p tection of the apparatus, this pipe may be locked by riveting a sh piece of chain to the cover and locking it to the bed piece.

The door and window frames are shown in detail in Plate XI The door and window frames should be placed flush with the outsi of the walls and the jambs set as shown in the details. When t has been done the 1-inch angles on the iron door and shutters will closely against the jambs, which will afford desirable protecti against storms and cold. The windows have 1⅜-inch stock sash each with four lights of 8 by 10 inch glass. Stops should be screw at the top and bottom of sash. The door should open inward a should be hung on 3-inch butts and provided with an ordina lock set.

In erecting the forms, care should be taken that all door and windo frames are properly set and are true to shape and dimensions. T hooks for the iron door and shutter hinges should be carefully place As shown on the plan, these hooks have a collar welded on, which fi flush with the outside wall, and the inside is provided with a nut a an ogee washer.

A top form is necessary for the roof slab. The form for the ove hanging eaves can be made of not more than two boards carried on series of brackets nailed to the uprights supporting the forms for th walls. The uprights may be wired together to preserve the line the walls. The pouring of the walls should be a continuous operatio up to within about a foot of the top. The walls for the remainin distance and the top slab should be poured at one operation. Sma holes and other defects in the face should be filled with mortar afte the forms are removed. Ridges or rough places may be smoothe down with a stick of carborundum. The entire face may be painte with a coat of thin mortar.

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TABLE 13.—*Bill of material for concrete well and shelter for automatic recording gage.*

[Lettered items refer to Plate VIII, p. 20.]

CONCRETE.

Item 1. 3.7 cubic yards 1–2–4 concrete in shelter, including floor, requiring—
22 bags cement.
1½ yards sand.
3 yards ¾-inch stone or gravel.

2. 2.7 cubic yards 1–2–4 concrete for upper 3 feet of well, requiring—
17 bags cement.
1¼ yards sand.
2½ yards stone.

3. 0.6 cubic yard (approximately) of 1–2–4 concrete in walls of well for each foot of depth below first 3 feet. Each cubic yard requires—
6.4 bags cement.
0.45 yard sand.
0.90 yard stone.

4. 1.2 cubic yards 1–3–6 concrete in foundation, requiring—
6 bags cement.
5⅔ yards sand.
11½ yards stone.

5. 62½ square feet Clinton wire cloth or substitute for reinforcing roof and floor.

6. One wooden doorframe *D*1, with door complete, with lock set, hinges, and four lights of glass.

7. One iron door *D*2, as shown on drawing, painted with one coat of Dixon's graphite paint, complete, with two staples for padlocks.

8. Eight hooks *H*1, fitted to hinges, with collars welded on, and furnished with nuts and ogee washers.

9. Three window frames *Q*, with sashes, complete.

10. Three iron shutters *DZ*, as shown on drawing, painted with one coat Dixon's graphite paint, with 6 staples for padlocks.

11. Four United States Geological Survey standard padlocks.

12. One lifting ring *U*, for trapdoor, with screws.

13. One pair 6-inch strap hinges *H*, with 4-inch stove bolts for all holes.

14. Two pieces light rail *C*, for door rest, each 3½ feet long.

15. 1 pound 1½-inch (6d.) nails, for trim.

16. Six pieces 3-inch galvanized wrought-iron pipe for ventilator, cut as follows:
One piece 6 feet 3 inches long, *O*, threaded one end.
One piece 1 foot long, *O*1, threaded one end.
One piece 2 feet long, *O*2, threaded one end.
One piece 1 foot long, *O*3, threaded both ends.
One piece 2 feet long, *O*4, threaded both ends.
One piece 7 inches long, *O*5, threaded one end.

17. Four 3-inch galvanized elbows *N N*1 *N*2 *N*3.

18. One 3-inch galvanized return bend *B*.

19. Four pieces 2-inch galvanized wrought-iron pipe *V*, 8 inches long, threaded one end, with four 2-inch galvanized caps, or else grid ventilators, if desired.

20. One 6-inch smoke jack *SJ*, with cap, as shown, over hook gage. (Use where hook gage rises above roof.)

21. One piece ¼ by 2 inches iron, 2 feet long, *S*, for stirrup.

22. One eyebolt *E*, ½ by 6 inches, with nut and 4 by 4 by ⅜ inch square washer.

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Item 23. —— pieces *R*, 1-inch iron 3 feet long, for steps, inner edge to
from face of wall.
24. —— one-half inch bolts *J*, with nuts and washers, to hold bed p
25. Two machine bolts *S*1, ¼ by 3½ inches, with washers to fasten
stirrup.
26. 1-gallon carbolineum for treating gage rod, table, etc.
27. 1 gallon gray mixed paint for door, window, etc.

MATERIAL FOR CAST-IRON INTAKE PIPE, ANCHORAGE, ETC.

Item 28. One 4 by 4 by 4 inch C. I. T, *PT*, for intake.
29. 1 square foot ½-inch mesh galvanized-iron wire screening.
30. 5 feet No. 10 galvanized wire.
31. One-half pound oakum and 5 pounds lead for each joint to be ca
32. —— bags cement for concrete for intake anchorage.
33. —— cubic yards sand for concrete for intake anchorage.
34. —— cubic yards gravel or broken stone for concrete for anchora
35. One 4-inch sluice valve *G*, with body of proper length.
36. —— feet ½-inch galvanized pipe *P*1, for valve stem.
37. —— lengths 4-inch standard-weight cast-iron pipe *P*2, for intake
38. Five straps and 10 anchor bolts *PS*, with nuts for holding intak

NOTE.—When wrought-iron pipe is used, omit oakum and lea

LUMBER.

Item 39. One piece lumber 2 by 6 inches by 14 feet, for trapdoor *T*.
40. Two pieces lumber 2 by 4 inches by 12 feet, for furring strips *A*.
41. Two pieces lumber 2 by 4 inches by 14 feet, for furring strips *A*.

NOTE.—All lumber throughout the building and well shall b
of the several kinds, thoroughly seasoned, free from large or unso
saps, shakes, wanes, dry rot, or other imperfections impairing its
durability or affecting its appearance for the purpose for which
used.

42. One standard gage table. (See Table 15, p. 38.)
43. One standard hook gage. (See Table 1, p. 9.)

FORMS.

[See p. 38.]

For a well 12 feet from bottom of floor to top of footing:

Item 44. Forty pieces 2 by 6 inches by 16 feet (640 feet b. m.), from which
Four pieces 8 feet 5 inches long, frames under bottom of house.
Four pieces 7 feet 5 inches long, frames under bottom of house.
Eight pieces 8 feet 3 inches long, outside frames for house.
Eight pieces 7 feet 3 inches long, outside frames for house.
Five pieces 5 feet 10 inches long, inside frames for house.
Ten pieces 4 feet 10 inches long, inside frames for house.
—— jack rafters to support edge form on roof.
Six pieces 2 feet 4 inches long, beams under floor.
Two pieces 8 feet 5 inches long, top outside corbel frame.
Two pieces 7 feet 5 inches long, top outside corbel frame.
Two pieces 8 feet 5 inches long, middle corbel frame.
Two pieces 6 feet 3 inches long, middle corbel frame.
Fourteen pieces 5 feet 4 inches long, outside well frame.
Fourteen pieces 8 feet 10 inches long, outside well frame.
Eighteen pieces 2 feet 4 inches long, inside well frame.

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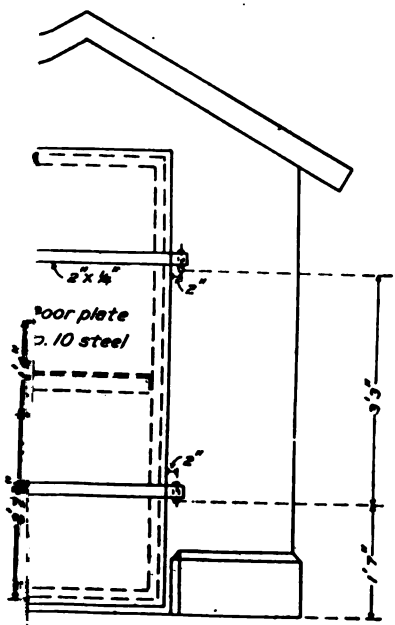
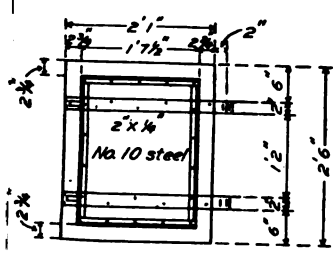
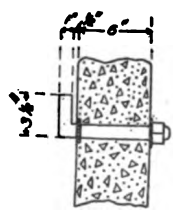


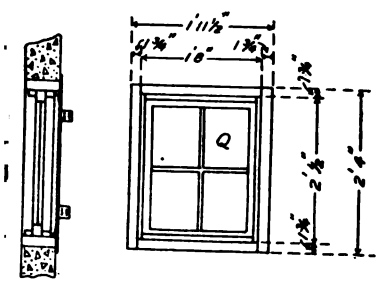
T ELEVATION



E. DETAILS OF WINDOW SHUTTER D2



DETAIL OF HOOK FOR HINGES H1



WINDOW DETAILS

RON DOOR AND SHUTTERS.

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Item 45. Sixteen pieces 2 by 6 inches by 12 feet (192 feet b. m.), from which cut—
Five pieces 5 feet 10 inches long, inside frames for house.
Nine pieces 5 feet 10 inches long, beams under roof forms.
Eighteen pieces 5 feet 10 inches long, inside frames for well.

46. Four pieces 2 by 4 inches by 12 feet (32 feet b. m.), from which cut—
Four pieces 3 feet long, inside cleats bottom of roof.
Four pieces 5 feet long, outside cleats bottom of roof.
Two pieces 5 feet 10 inches long, cleats under floor beams.

47. 1,100 feet b. m. 1-inch T. G. & S. or S. L. S. sheathing.

48. Braces and cleats in forms for footing.

49. —— telephone wire to tie forms together.

50. Ten pounds 8d. (2½-inch) wire nails.

51. Five pounds 20d. (4-inch) wire nails.

52. For each additional foot of depth of well increase item 43, 1-inch sheathing, by 50 feet b. m., and dimension lumber according to depth.

NOTE.—In these forms the sheathing for both well and house is placed vertically on the 2 by 6 inch framing pieces, which are placed horizontally. If necessary, 6 by 8 inch wale pieces, placed vertically, may be used to preserve the alignment of the forms.

SUMMARY OF LUMBER IN FORMS FOR A 12-FOOT WELL.

	Feet b. m.
In well:	
1-inch sheathing	620
Dimension lumber	475
Braces and cleats	±117
In shelter:	
1-inch sheathing	480
Dimension lumber	408
	±2,100

NOTE.—This bill includes a reasonable allowance for cuts, undersized pieces, and mistakes, but the cutting scheme shown in the table should be followed carefully.

REINFORCED-CONCRETE SHELTER.

If a reinforced-concrete shelter is desired, it should be built according to the plans shown in Plate IX (p. 20), in which all dimensions are given. The window frames (Pl. X, *A*, p. 22), which are of metal and contain wire screens, may be obtained from stock at builders' supply houses. Ventilators of pressed steel of a style similar to the window frames may also be obtained. A suitable fireproof door may be made by covering with block tin an ordinary door built of planks.

General directions for building the necessary forms are given on page 38.

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TABLE 14.—*Bill of material for reinforced-concrete shelter for automatic recording gage.*

[Lettered items refer to Plate IX, p. 20.]

CONCRETE.

Item 1. 7.9 cubic yards of 1–2–4 concrete, in shelter, corbel, and footing, requiring—
50 bags Portland cement.
4 cubic yard clean sharp sand.
8 cubic yard clean gravel or broken stone.

2. 23.8 cubic feet of concrete for each linear foot of well between bottom of corbel and top of footing course. Each cubic yard of concrete requires—
6.4 bags of Portland cement.
0.45 cubic yard of clean sharp sand.
0.90 cubic yard of clean gravel or broken stone.

STEEL REINFORCEMENT.

Use half-inch square deformed bars, unless otherwise specified. A lap of 2 feet is allowed to develop full strength of bars.

Item 3. Eighteen bars *C*1, 4 feet 10 inches long, joining walls to footing.
4. Four bars *C*2, 14 feet long, two at base of house and two over door.
5. Two bars *C*3, 12 feet 2 inches long, in corbel at top of well.
6. Two bars *C*4, 10 feet 4 inches long, in corbel at top of well.
7. —— bars *C*4, 10 feet 4 inches long, in well, spaced as depth of well may require.
8. Six bars *C*5, 11 feet 6 inches long, in side walls of house.
9. Two bars *B*1, 8 feet 6 inches long, placed lengthwise in footing.
10. Four bars *B*2, 7 feet 6 inches long, placed crosswise in footing.
11. Thirty-four bars *B*3, 7 feet long, in corbel at top of well.
12. Thirty-four bars *B*4, three-eighths inch square, 2 feet long, stirrups in footing.
13. —— bars *B*5, three-fourths inch round, 3 feet long, for steps, set 12 inches on centers, and with inner edge 3 inches from face of wall.
14. Fifteen bars *B*6, 4 feet long, to tie house to well.
15. Seven bars *S*6, 7 feet 8 inches long, placed lengthwise in roof.
16. Eight bars *S*7, 6 feet 8 inches long, placed crosswise in roof.
17. Sixteen bars *S*4, 7 feet 10 inches long, placed vertically in walls.
18. Two bars 6 feet 8 inches long, with ends hooked, placed over doors, back of *C*2.
19. One bar 6 feet 8 inches long, bent into four lengths and placed in doorstep.
20. Two bars *S*3, 6 feet long, crosswise in floor over well.
21. Six bars *S*1, 6 feet 4 inches long, lengthwise in footing.
22. Six bars *S*2, 5 feet 6 inches long, crosswise in footing.
23. Eighteen bars *S*8, of proper length, placed vertically in walls of well.
24. —— ⅝-inch hook bolts with nuts and one washer each to fasten staff gages to well.
25. One United States Geological Survey standard padlock.
26. Lifting ring and hinges for trap door. (See Table 13.)
27. Intake and valve. (For items see Table 13.)
28. One standard gage table (Table 15).
29. One standard hook-gage outfit (Table 1).
30. Carbolineum or other wood preservative for treating gages and gage table.
31. Necessary ventilators.

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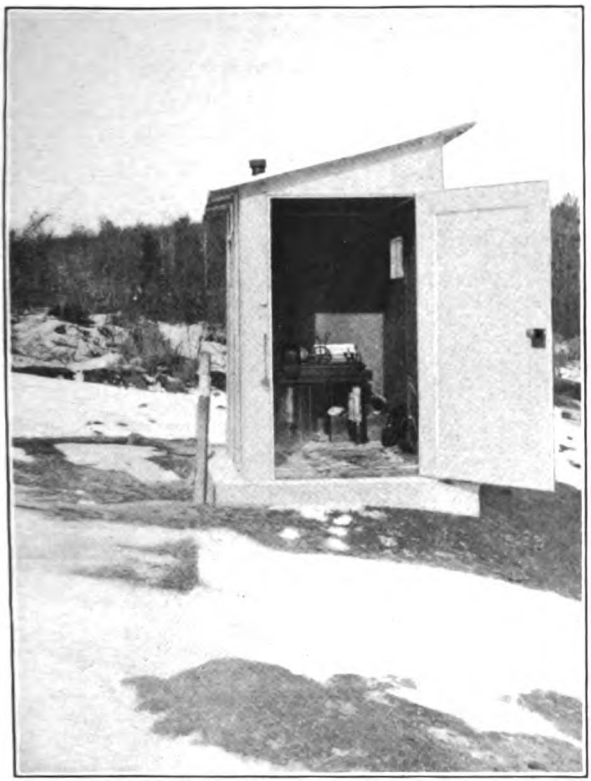

A. METAL SHELTER ON CONCRETE WELL.

Raquette River at Piercefield, N. Y.

B. SPECIAL SHELTER OF STONE.

Rio Grande at Embudo, N. Mex.

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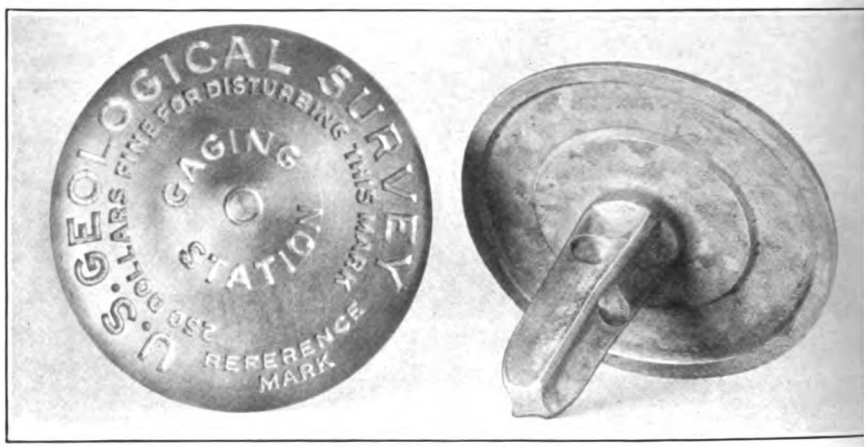
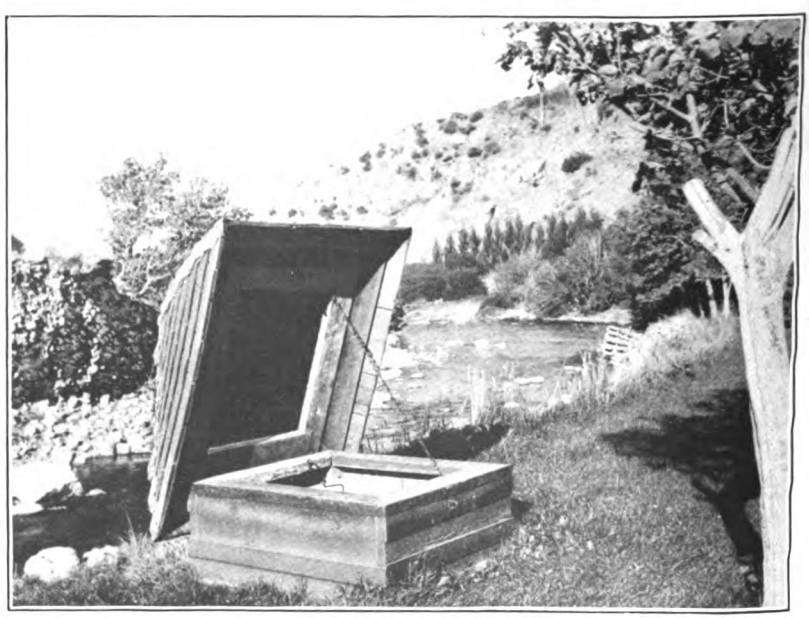


A. WATER RESOURCES BENCH-MARK TABLET.



B. LOW SHELTER.

Logan River at Logan, Utah.

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MISCELLANEOUS DESIGNS.

It is occasionally necessary to use local material, such as stone, brick, or wood-stave pipe, for building the shelter. The shelter shown in Plate XX, *B*, is built of stones backed by concrete. The roof is made of tile to avoid damage by fire from locomotive sparks. The wooden door is covered with tin, which is painted. In building the house, forms were made for the inside and mortar was poured between them and the stone wall. The resulting wall, which was fairly smooth, was painted with a finishing coat of thin grout. The well beneath this shelter is lined with concrete. A circular ventilating opening, 6 inches in diameter, is carried up through one of the walls and opens into the air about 2 feet below the roof.

A shelter that has proved satisfactory in Hawaii is shown in Plate XVII, *B* (p. 31). The frame, which is built of pine, is of standard dimensions and is covered with rubberoid roofing paper. At one station the wood-stave pipe used as the well lining was carried above the ground to form the shelter.

The combination of a concrete-lined well with either a wooden or a metal shelter, as shown in Plate XX, *A*, may be made to advantage.

A special form of shelter is shown in Plate XXI, *B*, under the tree to the left of the tailrace of the power station.

Shelters of other types are shown in Plates XXII, XXIII, and XXIV.

VENTILATION.

Excess moisture has caused inconvenience and in some places difficulty in automatic-gage shelters.

In warm weather the moisture rusts tools or iron parts and also distorts the hydrograph paper. At stations where the temperature is above freezing throughout the year the excess moisture may be prevented by making openings on all sides near the top, at the base, and under the eaves of the shelter, thus maintaining free circulation of air across the top of the well and through the shelter. The openings may be protected with a woven-wire, metal, or wooden-slot screen. Dust should be kept out of the shelter by stretching a piece of cheesecloth or thin muslin over the ventilators in the house.

Where the station must be maintained during cold weather the problem is more difficult. The well is then relatively warm and the air in it is saturated with moisture; the house under ordinary circumstances is relatively cold. Whenever saturated air from below enters the shelter it loses its surplus moisture on cooling, sometimes depositing frost on the tape operating the gage mechanism, causing the tape to freeze to the frame of the machine, and thus giving an erroneous record. To permit free circulation of air when the temperature is below freezing is out of the question, for the water in

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the well will freeze when exposed. If, on the other hand, the temperature in the shelter is higher than the temperature in the well, air which is saturated at the well temperature will not be saturated at the higher temperature of the shelter. The remedy in this case will be to have the temperature in shelter at least as high as that in the well, a condition that may be attained by building for warmth or by heating, or both, according to the prevailing winter temperature at the station. Though air circulation is desirable, frequent changes of air in cold weather and the consequent cooling of the temperature of the house will defeat the purpose sought. The ventilators in wells and shelters used in both hot and cold weather should therefore be so arranged that they may be freely used in warm weather and closed tight in cold weather.

GAGE TABLE.

The gage table is best made of three layers of 1-inch material, the middle layer running across the top and bottom layers, both of which run in the same direction. The three layers should be fastened together by 1½-inch screws, passing from the middle layer into the top and from the bottom layer into the middle, thus leaving a smooth top surface on which to set the gage. In placing the screws the location of the chain openings should be kept in mind.

The adjustable standard legs for the table are made of pieces of 1½-inch galvanized pipe 24 to 30 inches long, threaded on both ends, the threads being cut long and to a tight hand fit. One thread must have a left-hand and the other a right-hand thread. These threads fit into 1½ by 5 inch floor flanges, four of which are fastened to the floor and four to the under side of the gage table. One set of four flanges must have left-hand threads.

TABLE 15.—*Bill of material for standard gage table.*

[Lettered items refer to Plate VIII, p. 20.]

Item 1. Four floor flanges *M*, 1½ by 5 inches, with right-hand thread.
2. Four flanges *M*1, 1½ by 5 inches, with left-hand thread.
3. Four pieces 1½-inch galvanized wrought-iron pipe *P*, 24 inches long, with one right-hand and one left-hand thread on each. The threads are to be cut 2 inches long and are to be fitted in the shop to a tight hand fit.
4. One-half gross F. H. No. 14 wood screws, 2 inches long, for screwing flanges to table and for making trapdoor.
5. One-half gross F. H. No. 10 wood screws, 1½ inches long, for making gage table.
6. Two pieces cypress, or other wood, 1 by 6 inches by 12 feet, for gage table *Y*.

FORMS.

In building concrete wells forms for both outside and inside will ordinarily be necessary. In some places a single board on each side, against which the back filling is made, may serve as the outer form,

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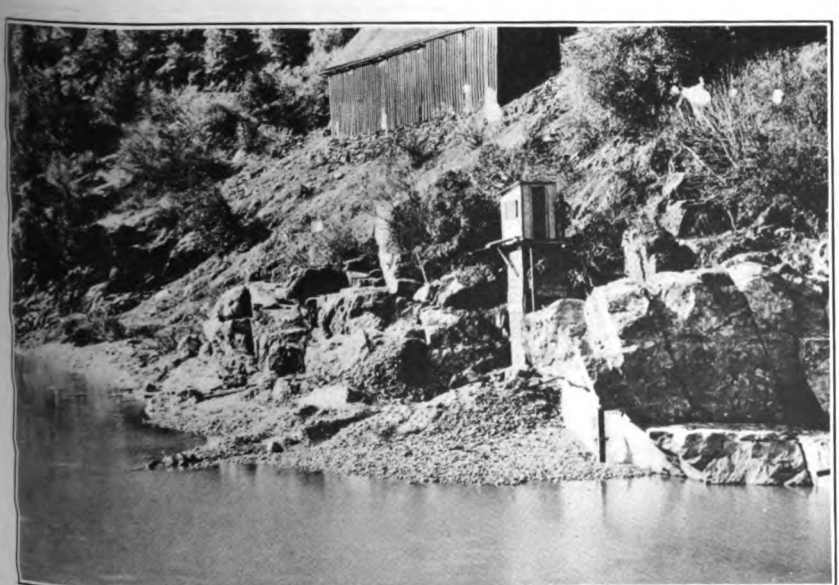
A. FEATHER RIVER AT OROVILLE, CAL.



B. NORTH FORK OF AMERICAN RIVER AT COLFAX, CAL.

AUTOMATIC-GAGE SHELTERS.

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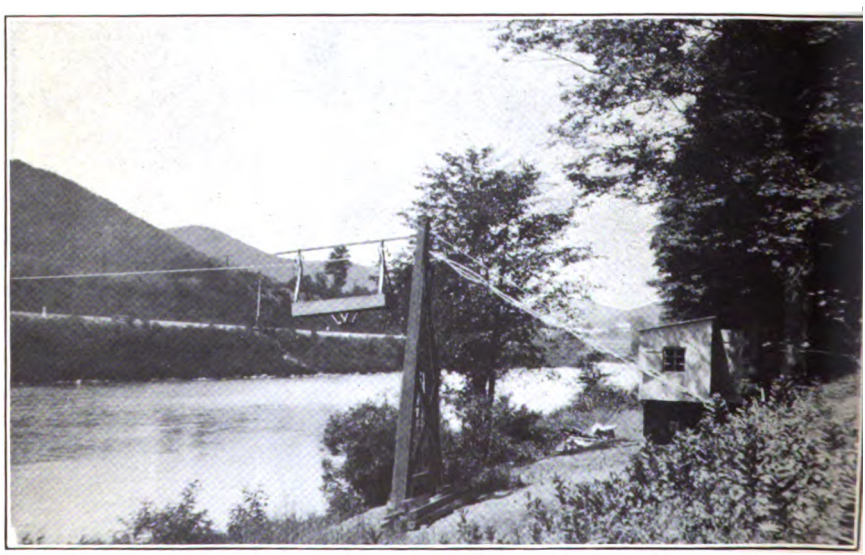
A. TUOLUMNE RIVER AT GROVELAND, CAL.



B. DEERFIELD RIVER AT CHARLEMONT, MASS.

AUTOMATIC-GAGE SHELTERS.

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boards being drawn up as the work progresses. It is highly ntial that the forms used should be tight; that is, the lumber used the forms should contain no large checks or knot holes. Rough, mber may, however, be made into smooth forms by covering ding paper. If reinforcing bars are used, care should be preserve the alignment of the bars while the forms are If expanded metal screen is used, the stone of the ould be small enough to pass the mesh of the expanded rwise the stones will arch behind the metal and the con- coarsely porous. A paddle made of 1-inch board may be the concrete into angles and recesses.

of the shelter may be finished smooth with a trowel or rough with a float, which may be made. In pouring the the roof, care should be taken to use only material of a stency. The use of material that is soupy will result in slime. When the concrete has set before the forms have it is necessary, before the work is continued, to remove ce down to unquestionably good concrete, to wash the with clean water, and then to paint it with rich grout. exterior of the shelter may be finished smooth by the use of rborundum finishing bricks, which are purchasable in any supply ouse.

The sluice valve and the iron steps must be placed in the inside forms. The use of narrow boards, with joints at the steps if possible, cilitate the removal of the forms. Bolts half an inch in diame- ced at 4-foot centers, should be provided for the attachment of piece for the hook gage. They should project such a distance wall that they will not reach the surface of the bed piece, hould be countersunk for the nuts. Expansion bolts of the type will be found convenient. A line of furring strips similar shown in the shelter (Pl. VIII, p. 20) would be convenient d around the well about 3 feet below the floor. A hook should provided in the wall over the sluice valve to hold the valve which should have a handle at its upper end. A very satisfac- valve stem may be made of half-inch galvanized pipe, with a end for fastening to the valve welded to one end and a handle welded to the other.

Openings necessary for ventilation should be provided for during construction.

The following designs for forms have been prepared for slow filling, as by hand from a small mix. Where conditions are such that the forms may be filled rapidly, as from a power mixer, the collars around the sheathing should be placed closer together to prevent bulging.

For the footing an outside form is built of sheathing braced against the pit.

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The outside forms for the well box consist of frames of 2 by 6 inch pieces laid flat, nailed together, and sheathed on the inside edges with planed 1-inch tongued-and-grooved or ship-lap boards placed vertically. The inside well forms are made of frames of material of the same size as used in the outside forms, the sheathing being in this case on the outside of the form. The alignment of the well forms is preserved by the use of 6 by 8 inch vertical waling strips.

The panel effect on the outside of the walls of the house is obtained by nailing strips of proper thickness to the 2 by 6 inch vertical studding before applying the sheathing horizontally. The 6 by 8 inch pieces are placed horizontally as collars around the forms for the house.

The first stage in pouring the concrete consists in bringing the walls and corbels up to the top of the floor, finishing the top surface, and leaving the tie rods *B*6 sticking up out of the concrete.

The forms are then built for the walls and roof, after which they are poured in one uninterrupted operation.

For the bottom of the floor of the concrete house the form consists of 1-inch sheathing nailed to 2 by 4 inch beams, resting on other 2 by 4 inch cleats, which are nailed to the sheathing for the well form. Forms for the roof are built of 1-inch sheathing supported by 2 by 6 inch beams nailed to the studs of the wall forms.

TABLE 16.—*Bill of material for concrete forms for reinforced-concrete well and shelter.*

This bill of material for lumber for forms is prepared for a well measuring 12 feet from the bottom of the corbel to the top of the footing.

Item 1. Twenty-three pieces 2 by 6 inches by 14 feet (322 feet b. m.), from which cut—
- Eighteen pieces 3 feet 10½ inches long, frames inside of well.
- Eighteen pieces 2 feet 10½ inches long, frames inside of well.
- Fourteen pieces 6 feet 8 inches long, frames outside of well.
- Fourteen pieces 5 feet 8 inches long, frames outside of well.

2. Twenty-two pieces 2 by 6 inches by 16 feet (352 feet b. m.), from which cut—
- Twenty-two pieces 8 feet long, studs outside of house.
- Eighteen pieces 7 feet 6 inches long, studs inside of house.
- Five pieces 5 feet long, under roof.

3. Two pieces 2 by 4 inches by 16 feet (21 feet b. m.), from which cut—
- Two pieces 8 feet 2 inches long, frame outside of corbel.
- Two pieces 7 feet 2 inches long, frame inside of corbel.

4. Three pieces 2 by 4 inches by 14 feet (28 feet b. m.), from which cut—
- Two pieces 7 feet 2 inches long, frame outside of corbel.
- Two pieces 6 feet 2 inches long, frame outside of corbel.
- Three pieces 3 feet long, under floor.

5. Twelve pieces 6 by 8 inches by 14 feet (672 feet b. m.), from which cut—
- Six pieces 8 feet long, waling strips outside of house.
- Six pieces 9 feet long, waling strips outside of house.
- Six pieces 4 feet long, waling strips inside of house.
- Six pieces 5 feet long, waling strips inside of house.

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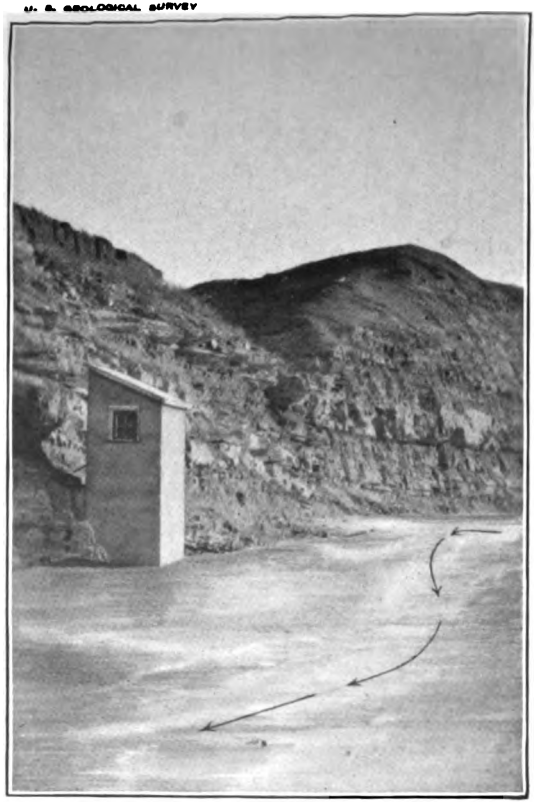

A. ST. MARYS RIVER AT INTERNATIONAL BOUNDARY.

B. CHENANGO RIVER AT CHENANGO FORKS, N. Y.

AUTOMATIC-GAGE SHELTERS.

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Item 6. Eight pieces waling strips on well.
7. 1,150 feet b. m. 1-inch T. G. & S. or S. L. S. 6 by 8 inches by 12 feet sheathing (384 feet b. m.).
8. Braces, cleats, and sheathing in forms for footings.
9. Twenty-four ¾-inch bolts, 13 inches long, to bolt house walers together.
10. —— telephone wire to tie well forms.
11. 10 pounds 8d. (2½-inch) wire nails.
12. 5 pounds 20d. (4-inch) wire nails.
13. 1 pound finishing nails for bevel pieces.
14. For each additional foot of depth of well increase the bill of 1-inch T. G. & S. lumber by 40 feet b. m. and of dimension lumber according to depth.

SUMMARY OF LUMBER IN THE ABOVE BILL.

	Feet b. m.
In well:	
1-inch sheathing	700
Dimension lumber	800
In shelter:	
1-inch sheathing	450
Dimension lumber	1,075
	3,025

NOTE.—This bill includes a reasonable allowance for cuts, undersized pieces, and mistakes, but the cutting scheme shown in the table should be followed carefully.

BENCH MARKS.

Too much care can not be taken to insure the permanence of the relation between the zero of the gage and the station bench marks.

Two independent bench marks at each station are desirable. At bridge stations at least one bench mark should be apart from the structure. A track spike with the front edge of the head upturned, driven into a tree, makes a useful bench mark. In a locality without timber the Water Resources bench mark (Pl. XXI, *A*, p. 37) may be used. To set it dig a small hole well below frost line with a post-hole digger. Fill the hole with concrete and into this set the bench-mark tablet. Always place the tablet with the axis of the stem vertical, so that the cross marking the elevation is actually the highest point of the bench mark.

Avoid placing bench marks on new or unstable structures. Wherever possible place the bench mark so that the gage may be reached in one set up.

STRUCTURES USED IN MAKING DISCHARGE MEASUREMENTS.

ESSENTIAL PARTS.

A structure to support the engineer while measuring velocity and depth, on a stream that is too large to permit making measurements by wading, is necessary at current-meter stations. Such a structure may be (1) a cable for carrying a car, or (2) an existing or specially constructed bridge, or (3) a boat held in position by a cable or guy line.

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The equipment and appurtenances for a cable station consist of the cable and its accessories, the supports and anchorages for sustaining it, and a car for carrying the observer.

CABLE EQUIPMENT.

SUPPORTS.

Standard designs for A frame supports from 8 to 20 feet in height are shown in Plates XXV, XXVI, XXVII, and XXVIII. Plate XXIX, *A*, shows a typical support in place. These standards represent the most approved type of construction. In Plate XXVI is shown another method of hanging the sheave which may be used where desired. A spacing block should be used either above or below the sheave.

In determining the height of frame consideration should be given the highest stage of water, the clearance required below the foot rest of the car, the distance between foot rest and car pulleys, and the loaded sag of the cable. The sizes of posts for frames of any height should be fixed by the requirements of the load, which varies with the length of span. A bill of material is given for three or more post sizes for each frame height illustrated.

In all designs the main posts should be framed with a 1 in 5 batter, the distance across the top of the frame should be three-fourths inch less than the length of the top plate, and the spread at the bottom should be as shown in the drawings. The inside dimensions of frames are fixed by the height of frame, the use of the larger sizes of posts increasing only the outside dimensions. The longer cross-sectional dimension of the post should be placed parallel to the cable.

The frames should be supported on mud sills, concrete piers, or other foundations that will distribute the load satisfactorily.

When concrete or other piers are used, provision should be made for fastening the frames to the piers. Such fastening may be accomplished by pairs of ¾-inch bolts set into the concrete 1 foot inside the posts, the bolts of each pair being spaced far enough apart to allow the sill *A* to pass between them. An iron strap ½ inch by 2 inches, bored to receive the bolts, should be placed on the sill and screwed down to the bolts to hold it in place.

To prevent the A frame from falling forward, a backstay of proper size should be carried through a turnbuckle to the anchorage. The backstay may be attached either to the eyebolt carrying the sheave or to a U bolt of 2-inch spread and sufficient length to pierce the posts 3 inches below the top plate. A Crosby clip is placed on the cable just back of the sheave to prevent the frame from falling backward.

A ladder for gaining access to the cable car is made by using iron telephone steps in one of the posts *B*, as shown in Plate XXVI.

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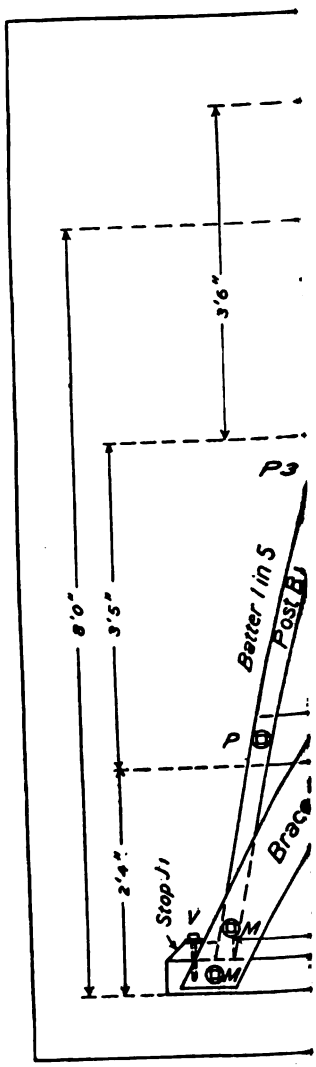

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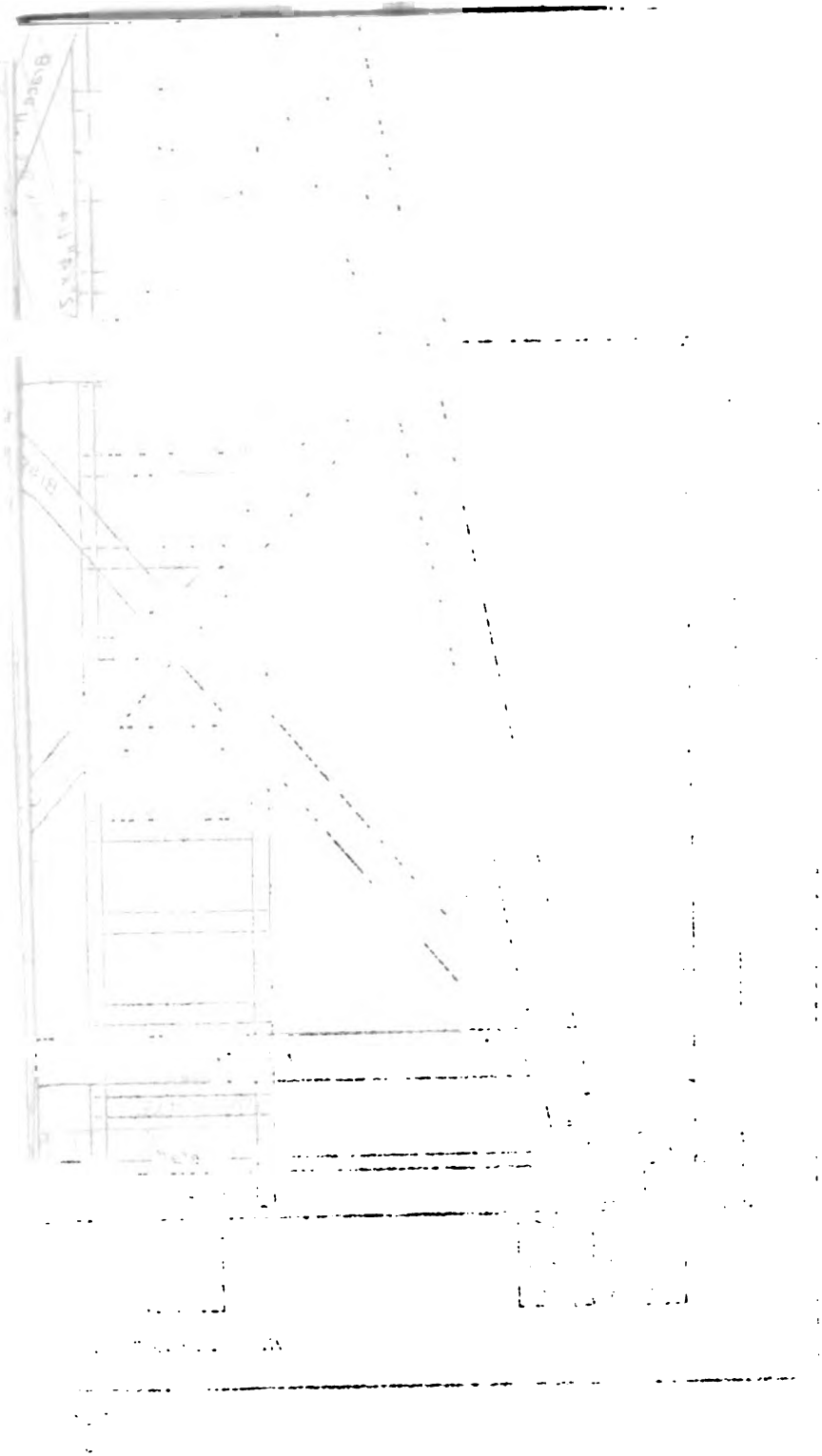

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Otherwise a wooden ladder may be used, as shown in Plate XXVIII, the rounds of the ladder being spiked to the poles, or gained in and fastened with a ½ by 4 inch carriage bolt, with a washer on the inside.

All timber used in the construction of the frames should be the best of its kind, thoroughly seasoned, and free from large or unsound knots, sap, shakes, wanes, dry rot, or other imperfections impairing its strength, durability, or appearance. All A frames must be given two coats of gray paint immediately after construction.

All top plates, as shown in Plate XXVIII, should be one-half inch thick and should have a 1⅝-inch hole through the center. All side plates should be three-eighths of an inch thick. Side plates for 8-foot frames with 2 by 6 inch posts should have ¾-inch holes; all other side plates should have ⅞-inch holes. The length and breadth of top and side plates, length of head bolts, and spacing of holes in side plates are shown in the tables following.

TABLE 17.—*Dimensions of top and side plates and bolts.*

Height of A frame.	Size of posts.	Top plate.[a]	Side plate.	Length of ¾-inch head bolts.	
				Upper.	Lower.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
8 feet (Pl. XXV)	2 by 6	(b)	(b)	(b)	(b)
	4 by 6	6 by 6	6 by 6	10	11
	6 by 6	6 by 10¾	6 by 6	15	16
12 feet (Pl. XXVI)	4 by 6	6 by 6	6 by 6	10	11
	6 by 6	6 by 10¾	6 by 6	15	16
	6 by 8	8 by 10¾	6 by 8	15	16
16 feet (Pl. XXVII)	4 by 6	6 by 6	6 by 6	10	11
	6 by 6	6 by 10¾	6 by 6	15	16
	6 by 8	8 by 10¾	6 by 8	15	16
	8 by 8	8 by 15	6 by 8	19	20
20 feet (Pl. XXVIII)	6 by 6	6 by 10¾	6 by 6	15	16
	6 by 8	8 by 10¾	6 by 8	15	16
	8 by 8	8 by 15	6 by 8	19	20
	8 by 10	10 by 15	6 by 10	19	20

[a] Distance across top of posts *B* is three-fourths inch less than length of top plate.
[b] Special head plate with half-inch bolts.

TABLE 18.—*Spacing of holes in side plates.*

Side plates for posts.	Dimensions.					
	a.	b.	c.	e.	f.	h.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
4 by 6 and 6 by 6 inches	2	2	2	1¾	2½	1¾
6 by 8 and 8 by 8 inches	2	4	2	2	2	2
8 by 10 inches	2½	5¾	2½	3	0	3

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The length m of eyebolt X (Pl. XXVIII), which is furnished wit the sheave S, should be 22 inches in all cases, except for the 8-fo frame with 2 by 6 inch posts, in which the dimension m should be 1 inches. A thread 3 inches long should be cut on eyebolts. A nu and ogee washer should be furnished with the eyebolt.

The cable should always be carried on a movable support, prefe ably a sheave of fairly large diameter, and not on a cradle of eith wood or metal.

The block which carries the cable is a very important detail of th support. The standard block and sheave have been designed t carry the maximum stress shown in Table 25 (p. 51). It should b made up of a 10-inch sheave of proper size for the cable, a 1-inch pin and a strap, made from round iron flattened, of the dimensions show on the drawing.

The arrangement of the sheave for carrying the cable shown i Plate XXVI may be substituted for the block when desired. I consists of two pieces, TS, of 4 by $\frac{3}{8}$-inch flat steel, bent to fit the top of the posts B, and long enough to take the two 1-inch holes for th 1-inch bolt AS. Bevel washers W are used against the post. Th dimension of the top of post B is given in Table 17.

TABLE 19.—*Bill of material for 8-foot frames.*

[Lettered items refer to Plates XXV, XXVI, XXVII, and XXVIII.]

Items.	Number of pieces.	2 by 6 inch posts.	4 by 6 inch posts.	6 by 6 inch posts.
A1, sill	1	4 by 6 inches by 5 feet.	6 by 6 inches by 5 feet.	6 by 6 inches by 5 feet.
B1, posts	2	2 by 6 inches by 9 feet.	4 by 6 inches by 9 feet.	6 by 6 inches by 9 feet.
C1, cross braces	2	1½ by 6 inches by 6 feet 6 inches.	1½ by 6 inches by 6 feet 6 inches.	2 by 6 inches by 6 feet 6 inches.
D1, brace	1	2 by 6 inches by 3 feet 3 inches.	2 by 6 inches by 3 feet 3 inches.	2 by 6 inches by 3 feet 6 inches.
E1, brace	1	2 by 6 inches by 2 feet.	2 by 6 inches by 2 feet 3 inches.	2 by 6 inches by 2 feet 6 inches.
J1, stops	2	2 by 6 by 6 inches	4 by 6 by 6 inches	4 by 6 by 6 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer			as per Plate XXVIII.
W, bevel washers	4	See Plate XXVIII	See Plate XXVIII	See Plate XXVIII.
T1, top plate	1	See Plate XXVIII	See Table No. 17	See Table 17.
P1, side plates	2	do	do	Do.
N, head bolts	1	½ by 9 inches	do	Do.
	1	½ by 10 inches	do	Do.
M, sill bolts	[a] 4	½ by 8½ inches	½ by 8½ inches	¾ by 8½ inches.
P, post bolts	[a] 2	do	do	6 bolts ¾ by 8½ inches.
P3, post bolts	[a] 2	½ by 10½ inches	½ by 10½ inches	6 bolts ¾ by 10½ inches.
V, lag screws	[a] 2	½ by 5 inches	½ by 7 inches	½ by 7 inches.
T, crossing bolt	1	½ by 4 inches	½ by 4 inches	½ by 4½ inches.
Gray mixed paint		½ gallon	1 gallon	1 gallon.

[a] With 2 flat washers each. One washer only for lag screws.

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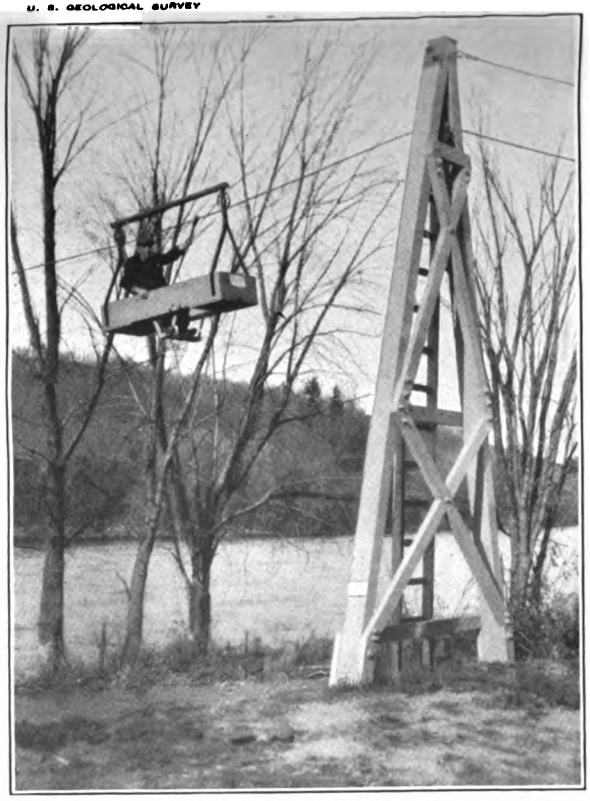
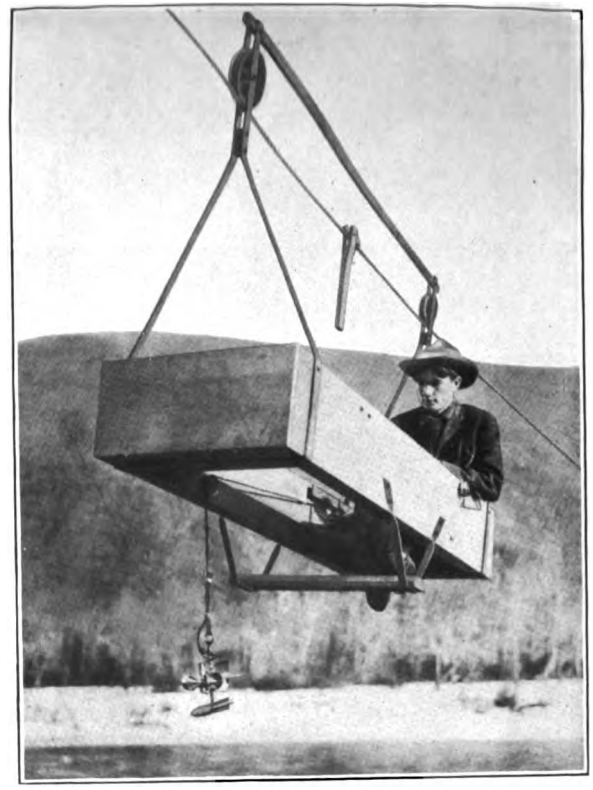


A. STANDARD "A" FRAME IN PLACE.



B. STANDARD CABLE CAR.

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TABLE 20.—*Bill of material for 12-foot frames.*

Items.	Number of pieces.	4 by 6 inch posts.	6 by 6 inch posts.	6 by 8 inch posts.
A2, sill	1	6 by 6 inches by 8 feet	6 by 6 inches by 8 feet 3 inches.	6 by 8 inches by 8 feet 3 inches.
B2, posts	2	4 by 6 inches by 14 feet.	6 by 6 inches by 14 feet.	6 by 8 inches by 14 feet.
C2, cross braces	2	2 by 6 inches by 9 feet 6 inches.	2 by 6 inches by 9 feet 6 inches.	2 by 6 inches by 9 feet 6 inches.
D2, brace	1	2 by 6 inches by 5 feet 3 inches.	2 by 6 inches by 5 feet 6 inches.	2 by 6 inches by 5 feet 6 inches.
E2, brace	1	2 by 6 inches by 3 feet 8 inches.	2 by 6 inches by 4 feet	2 by 6 inches by 4 feet.
F2, brace	1	2 by 6 inches by 2 feet	2 by 6 inches by 2 feet 4 inches.	2 by 6 inches by 2 feet 4 inches.
G2, brace	1	2 by 4 inches by 2 feet 8 inches.	2 by 4 inches by 3 feet	2 by 4 inches by 3 feet.
J2, stops	2	4 by 6 inches by 1 foot 3 inches.	4 by 6 inches by 1 foot 3 inches.	4 by 6 inches by 1 foot 3 inches.
L2, ladder poles	2	2 by 4 inches by 10 feet.	2 by 4 inches by 10 feet.	2 by 4 inches by 10 feet.
R, ladder rounds	8	1½ by 2 inches by 1 foot 9 inches.	1½ by 2 inches by 1 foot 9 inches.	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per Plate XXVIII.			
W, bevel washers	4	See Plate XXVIII	See Plate XXVIII	See Plate XXVIII.
T2, top plate	1	See Table 17	See Table 17	See Table 17.
P2, side plates	2	do	do	Do.
N, head bolts	[a] 2	do	do	Do.
M, sill bolts	[a] 4	½ by 8½ inches	½ by 8½ inches	¾ by 13 inches.
P, post bolts	[a] 8	do	do	¾ by 11 inches.
Q, post bolts	[a] 2	do	do	¾ by 15 inches.
T, crossing bolt	[a] 1	½ by 4 inches [b]	½ by 5 inches [b]	½ by 5 inches.[b]
Y, ladder bolts	[a] 4	½ by 7 inches	½ by 7 inches	½ by 7 inches.
Z, eyebolt	[a] 1	½-inch eyebolt, shank 2½ inches long, with 6 feet of galvanized pump chain.		
V, lag screws	4	½ by 8 inches	½ by 8 inches	½ by 8 inches.
Gray mixed paint		½ gallon	½ gallon	1 gallon.

[a] With 2 flat washers each. One washer only on lag screw.
[b] This length when cross braces are halved; 2 inches longer when they overlap.

If iron telephone steps are used omit all ladder items and make post bolts Q 4 inches shorter.

TABLE 21.—*Bill of material for 16-foot frames.*

Items.	Number of pieces.	4 by 6 inch posts.	6 by 6 inch posts.
A3, sill	1	6 by 6 inches by 9 feet	6 by 8 inches by 9 feet.
B3, posts	2	4 by 6 inches by 18 feet	6 by 6 inches by 18 feet.
C3, cross braces	2	2 by 6 inches by 9 feet	2 by 6 inches by 9 feet.
H3, cross braces	2	2 by 6 inches by 7 feet	2 by 6 inches by 7 feet.
D3, brace	1	2 by 6 inches by 7 feet 3 inches	2 by 6 inches by 7 feet 3 inches.
E3, brace	1	2 by 6 inches by 4 feet 3 inches	2 by 6 inches by 4 feet 8 inches.
F3, brace	1	2 by 6 inches by 2 feet	2 by 6 inches by 2 feet 3 inches.
G3, brace	1	do	Do.
J3, stops	2	4 by 6 inches by 1 foot	4 by 6 inches by 1 foot.
K3, cleats	4	4 by 6 inches by 1 foot 9 inches	4 by 6 inches by 1 foot 9 inches.
L3, ladder poles	2	2 by 4 inches by 14 feet	2 by 4 inches by 14 feet.
R, ladder rounds	13	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer, as per Plate XXVIII.		
W, bevel washers	4	See Plate XXVIII	See Plate XXVIII.
T3, top plate	1	See Table 17	See Table 17.
P3, side plates	2	do	Do.
N, head bolts	2	do	Do.
M, sill bolts	[a] 6	¾ by 11 inches	¾ by 11 inches.
P, post bolts	[a] 6	do	Do.
Q, post bolts	[a] 2	¾ by 15 inches	¾ by 15 inches.
Q1, post bolts	[a] 2	¾ by 9 inches	¾ by 9 inches.
T, crossing bolts	1	½ by 3 inches [b]	½ by 3 inches.[b]
Y, ladder bolts	4	½ by 7 inches	½ by 7 inches.
Z, eyebolt	1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	[a] 4	½ by 8 inches	½ by 8 inches.
Gray mixed paint		2 gallons	2 gallons.

[a] With posts over 6 by 6 inches cross section use ogee washers. The additional thickness of ogee washers is allowed for in billing the bolt. For 6 by 6 inches or less use flat washers, 2 on each bolt and 1 on each lag screw.
[b] This length when cross braces are halved; 2 inches longer when they overlap.

If iron telephone stops are used omit all ladder items and make post bolts Q 4 inches shorter.

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TABLE 21.—*Bill of material for 16-foot frames*—Contin

Items.	Number of pieces.	6 by 8 inch posts.	8 by
A3, sill	1	6 by 8 inches by 9 feet	8 by 10 inch
B3, posts	2	6 by 8 inches by 18 feet	8 by 8 inche
C3, cross braces	2	2 by 6 inches by 9 feet	3 by 6 inche
H3, cross braces	2	2 by 6 inches by 7 feet	3 by 6 inche
D3, brace	1	2 by 6 inches by 7 feet 3 inches	3 by 8 inches
E3, brace	1	2 by 8 inches by 4 feet 8 inches	3 by 8 inches
F3, brace	1	2 by 6 inches by 2 feet 3 inches	3 by 6 inches
G3, brace	1	2 by 6 inches by 2 feet 3 inches	3 by 6 inches
J3, stops	2	4 by 6 inches by 1 foot	4 by 6 inches
K3, cleats	4	2 by 6 inches by 1 foot 9 inches	3 by 6 inches
L3, ladder	2	2 by 4 inches by 14 feet	2 by 4 inches
R, ladder rounds	13	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per		
W, bevel washers	4	See Plate XXVIII	See Plate XX
T3, top plate	1	See Table 17	See Table 17.
P3, side plates	2	do	Do.
N, head bolts	2	do	Do.
M, sill bolts	[a] 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	[a] 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	[a] 2	¾ by 12½ inches	¾ by 13½ inches.
Q, post bolts	[a] 2	¾ by 18½ inches	¾ by 20½ inches.
T, crossing bolts	[a] 1	¾ by 4½ inches [b]	¾ by 5½ inches. [b]
Y, ladder bolts	4	½ by 7 inches	½ by 8 inches.
Z, eyebolt	[a] 1	½ inch by same length as crossing bolt, with nut and vanized pump chain.	
V, lag screws	[a] 4	½ by 8 inches	½ by 8 inches.
Gray mixed paint		2½ gallons	2½ gallons.

[a] With posts over 6 by 6 inches cross section use ogee washers. The additional thickness of [illegible] is allowed for in billing the bolt. For 6 by 6 inches or less use flat washers, 2 on each bolt and lag screw.

[b] This length when cross braces are halved; 2 inches longer when they overlap.

If iron telephone steps are used omit all ladder items and make post bolts Q 4 inches shorter.

TABLE 22.—*Bill of material for 20-foot frames.*

Items.	Number of pieces.	6 by 6 inch posts.	6 by 8 inch post
A4, sill	1	6 by 8 inches by 11 feet	6 by 8 inches by 11 feet
B4, posts	2	6 by 6 inches by 22 feet	6 by 8 inches by 22 feet.
C4, cross braces	2	3 by 6 inches by 10 feet 9 inches	3 by 6 inches by 10 feet 9
H4, cross braces	2	3 by 6 inches by 9 feet 6 inches	3 by 6 inches by 9 feet 6 i
D4, brace	1	3 by 6 inches by 9 feet	3 by 6 inches by 9 feet.
E4, brace	1	3 by 8 inches by 5 feet 10 inches	3 by 8 inches by 5 feet 10 i
F4, braces	1	3 by 6 inches by 2 feet 3 inches	3 by 6 inches by 2 feet 3 i
G4, brace	1	3 by 6 inches by 2 feet 3 inches	3 by 6 inches by 2 feet 3 in
J4, stops	2	3 by 6 inches by 1 foot	3 by 6 inches by 1 foot.
K4, cleats	4	3 by 6 inches by 1 foot 6 inches	3 by 6 inches by 1 foot 6 in
L4, ladder poles	2	2 by 4 inches by 19 feet	2 by 4 inches by 19 feet.
R, ladder rounds	17	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 in
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per Plate XX		
W, bevel washers	4	See Plate XXVIII	See Plate XXVIII.
T4, top plate	1	See Table 17	See Table 17.
P4, side plates	2	do	Do.
N, head bolts	[a] 2	do	Do.
M, sill bolts	[a] 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	[a] 6	¾ by 14½ inches	¾ by 16½ inches.
P1, post bolts	[a] 2	¾ by 11½ inches	¾ by 13½ inches.
Q, post bolts	[a] 2	¾ by 18½ inches	¾ by 20½ inches.
T, crossing bolt	[a] 1	¾ by 5½ inches	¾ by 5½ inches.
Y, ladder bolts	4	½ by 8 inches	½ by 8 inches.
Z, eyebolt	[a] 1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	[a] 4	½ by 7 inches	½ by 7 inches.
Gray mixed paint		2 gallons	2 gallons.

[a] On 20-foot frames use ogee washers. These are approximately three-fourths inch thick, which additional thickness is allowed for in billing the bolt. Use 1 flat washer on each lag screw and 2 on ladder bolts.

If iron telephone steps are used omit all ladder items and make post bolts Q 4 inches shorter.

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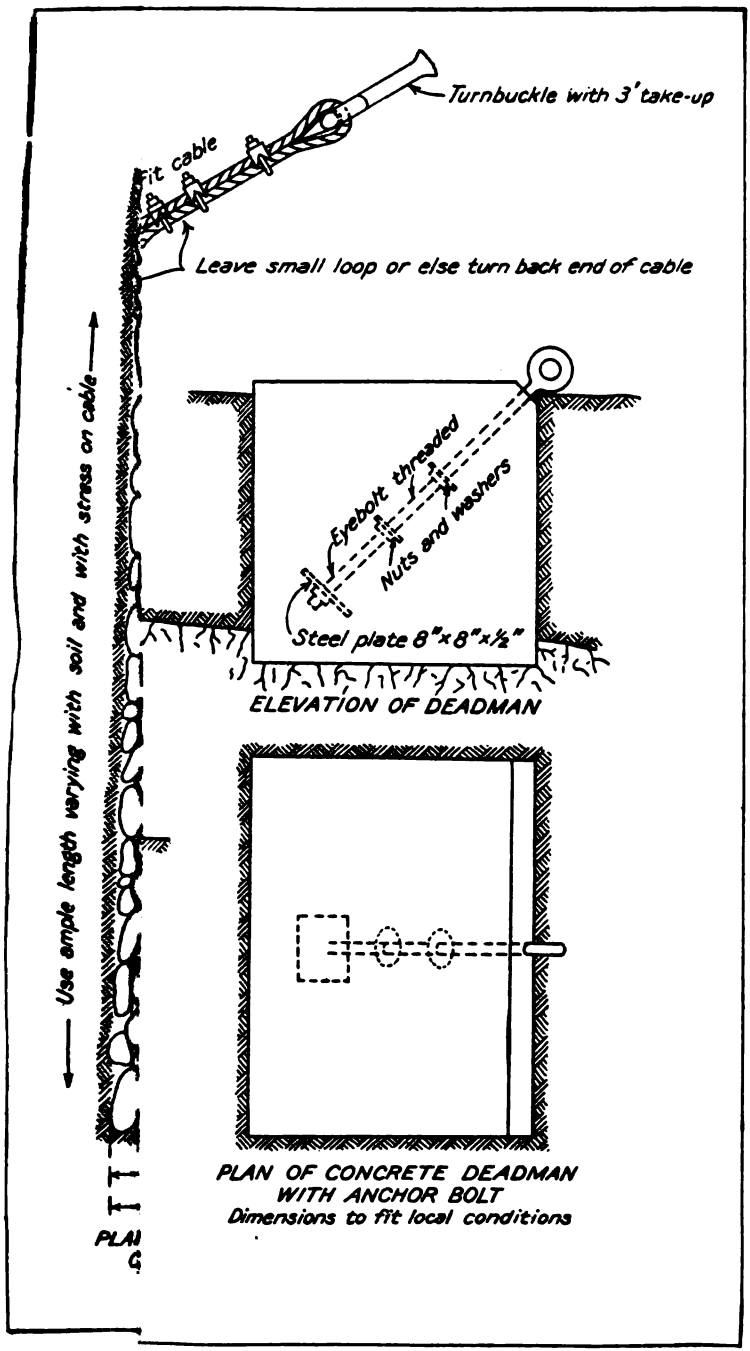

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TABLE 22.—*Bill of material for 20-foot frames*—Continued.

Items.	No. of pieces.	8 by 8 inch posts.	8 by 10 inch posts.
A4, sill	1	8 by 10 inches by 11 feet 3 inches.	8 by 10 inches by 11 feet 3 inches.
B4, posts	2	8 by 8 inches by 22 feet	8 by 10 inches by 22 feet.
C4, cross braces	2	3 by 6 inches by 10 feet 9 inches.	3 by 6 inches by 10 feet 9 inches.
H4, cross braces	2	3 by 6 inches by 9 feet 6 inches	3 by 6 inches by 9 feet 6 inches.
D4, braces	1	3 by 6 inches by 9 feet 4 inches	3 by 6 inches by 9 feet 4 inches.
E4, brace	1	3 by 8 inches by 6 feet 2 inches	3 by 8 inches by 6 feet 2 inches.
F4, brace	1	3 by 6 inches by 2 feet 7 inches	3 by 6 inches by 2 feet 7 inches.
G4, brace	1	3 by 6 inches by 2 feet 7 inches	3 by 6 inches by 2 feet 7 inches.
J4, stops	2	3 by 8 inches by 1 foot	3 by 10 inches by 1 foot.
K4, cleats	4	3 by 8 inches by 1 foot 6 inches	3 by 8 inches by 1 foot 6 inches.
L4, ladder poles	2	2 by 4 inches by 19 feet	2 by 4 inches by 19 feet.
R, ladder rounds	17	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per Plate XXVIII.		
W, bevel washers	4	See Plate XXVIII	See Plate XXVIII.
T4, top plate	1	See Table 17	See Table 17.
P4, side plates	2	do	Do.
N, head bolts	[a] 2	do	Do.
M, sill bolts	[a] 6	¾ by 16½ inches	¾ by 18½ inches.
P, post bolts	[a] 6	¾ by 16½ inches	¾ by 18½ inches.
P1, post bolts	[a] 2	¾ by 13½ inches	¾ by 15½ inches.
Q, post bolts	[a] 2	¾ by 20½ inches	¾ by 22½ inches.
T, crossing bolt	[a] 1	¾ by 5½ inches	¾ by 5½ inches.
Y, ladder bolts	4	½ by 8 inches	½ by 8 inches.
Z, eyebolt	[a] 1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	[a] 4	⅝ by 7 inches	⅝ by 7 inches.
Gray mixed paint		3 gallons	3 gallons.

[a] On 20-foot frames use ogee washers. These are approximately three-fourths inch thick, which additional thickness is allowed for in billing the bolt. Use 1 flat washer on each lag screw and 2 on ladder bolts.

If iron telephone stops are used omit all ladder items and make post bolts Q 4 inches shorter.

ANCHORAGES.

COMMON TYPES.

The most usual types of anchorages for cables are deadmen, trees, and rock ledges. Designs of timber and concrete deadmen are shown in Plate XXX. The anchorages should always be so placed that they may be readily inspected. A station record showing the type, construction features, and date of installation of anchorages should be kept. Timber deadmen should be thoroughly inspected at least once in four years to determine the condition of the timber.

DEADMEN.

The timber for deadmen should be carefully selected. Logs rather than dimension timber should be used. All timber should be sound, durable, and cleaned of all bark and foreign matter. Carbolineum or creosote should be used as a preservative; if neither is available, the timber may be charred.

No deadmen should be less than 12 inches in diameter nor less than 8 feet long. All deadmen should be so constructed as to provide a large factor of safety. The length of the stick and the depth to which it should be buried will depend on the stress on the cable and the nature of the soil. In ordinary loam, clay, or sand the depth should not be less than 6 feet. Additional bearing power may be given by inserting pieces of plank in front of the deadmen. The cable should

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ROCK LEDGES.

A rock ledge is in many places the only available a[illegible] ledge must be carefully examined before it is used, [illegible] cline fissures or faults, the texture of the rock not [illegible] ledge, and the thickness of the ledge measured if po[illegible] and prove durable and heavy enough, a hole should [illegible] 18 inches deep and 2 inches in diameter [illegible] bolt should be made of 1½-inch steel, with a split or [illegible] provided with a steel wedge, and an eye with a ship-ey[illegible] other end. The bolt should be sledged into the hole u[illegible] has expanded the split as far as possible. The remaini[illegible] to the face of the ledge, should be filled with neat Port[illegible] grout and left to set for 48 hours before the load is put o[illegible] Sulphur, stibnite and lead, Bahbitt metal, or brimstone [illegible] for the filling. In many places these are preferred to c[illegible]

A very secure fastening may be made on top of a le[illegible] bolt, with square head, square, made of 1½-inch round [illegible] ground of the bolt should be 12 inches and the length of [illegible] inches. The U bolt, inverted, is placed into two holes dr[illegible] with the cable and fastened as described above for the eye [illegible] cable should be passed through the U bolt and fastened [illegible] clips, a thimble being used to protect the cable. Three [illegible] cables be used by arranging them in a triangular position [illegible] upon inverted bolts. The cable is then run through the [illegible] and fastened by cable clips.

CABLES AND ATTACHMENTS.

THE CABLE.

The cable should be composed of six strands, each strand [illegible] ing seven wires around a hemp center. The material shoul[illegible] best quality plow steel. The cable should be galvanized and [illegible] be one continuous piece, no splicing being allowed. As a r[illegible] cable must be ordered from the factory, as few dealers carry [illegible] cable must be ordered in stock.

The sizes of cable are regarded as standard—¾-inch cable for [illegible] inch cable for spans between 400 and 650 feet [illegible]

The proper loaded sag for each span must be determined fro[illegible] sag diagram, Plate XXXI, in order not to exceed the standard [illegible] sag diagram in the cable.

Tables 25, 26, and 27 show functions of other than standard [illegible] of cable. These, together with Plate XXXI, cover the range [illegible] ordinary requirements.

The calculations for cables are based upon the method publi[illegible] by J. C. Stearns in Engineering News, May 6, 1909. A wo[illegible]

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TABLE 12.—*Bill of material for 8-foot frame—Continued.*

[illegible]	No. of pieces.	Size of timber parts.	Size of bolt parts.
[illegible]	1	[illegible] by 12 inches by 12 feet 12 inches	[illegible] by 12 inches by 12 feet 12 inches.
[illegible]	2	[illegible] by 6 inches by 12 feet	[illegible] by 12 inches by 12 feet.
[illegible]	2	[illegible] by 10 feet 6 inches	[illegible] by 6 inches by 10 feet 6 inches.
[illegible]	2	[illegible] by 10 feet 6 inches	[illegible] by 6 inches by 10 feet 6 inches.
[illegible]	1	[illegible] by 10 feet 6 inches	[illegible] by 6 inches by 10 feet 6 inches.
[illegible]	1	[illegible] by 6 inches by 6 feet 2 inches	[illegible] by 6 inches by 6 feet 2 inches.
[illegible]	1	[illegible] by 6 inches by 2 feet 7 inches	[illegible] by 6 inches by 2 feet 7 inches.
[illegible]	1	[illegible] by 6 inches by 2 feet 7 inches	[illegible] by 6 inches by 2 feet 7 inches.
[illegible]	2	[illegible] by 6 inches by 1 foot	[illegible] by 6 inches by 1 foot.
[illegible]	4	[illegible] by 6 inches by 1 foot 6 inches	[illegible] by 6 inches by 1 foot 6 inches.
[illegible]	2	[illegible] by 6 inches by 10 feet	[illegible] by 6 inches by 10 feet.
[illegible]	17	[illegible] by 2 inches by 1 foot 10 inches	[illegible] by 2 inches by 1 foot 10 inches.
[illegible]	1	[illegible] complete with washer, nut, and cotter washer as per Plate [illegible]	
[illegible]	6	See Plate [illegible]	See Plate [illegible]
[illegible]	1	See Plate [illegible]	See Plate [illegible]
[illegible]	2	do	do
[illegible]	2	do	do
[illegible]	4	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]	4	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]	2	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]	2	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]	4	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]	4	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]	2	Stock for spare length as remaining and, with the stock for the right-hand, spare shoes.	
[illegible]	4	[illegible] by [illegible] inches	[illegible] by [illegible] inches.
[illegible]		[illegible]	[illegible]

[illegible] are spare washers. There are approximately [illegible] [illegible] which should be allowed for in filling the bill. The [illegible] number [illegible]

[illegible] shops are used small all bolster boxes and make good [illegible]

ANCHORAGES.

COMMON TYPES.

[illegible] usual types of anchorages for cables are deadmen, tree, [illegible]dges. Designs of timber and concrete deadmen are shown [illegible] XX. The anchorages should always be so placed that they [illegible]ually inspected. A station record showing the type, co[illegible] features, and date of installation of anchorages should be [illegible]. Timber deadmen should be thoroughly inspected at least once [illegible] years to determine the condition of the timber.

TIMBER.

[illegible]mber for deadmen should be carefully selected. Large rubber [illegible] dimension timber should be used. All timber should be sound, [illegible], and cleaned of all bark and foreign matter. Creosote should be used as a preservative. If timber is available, [illegible] timber may be charred.

[illegible] deadmen should be less than 12 inches in diameter and less than [illegible] feet long. All deadmen should be so constructed as to provide a [illegible] factor of safety. The length of the stick and the depth to which it should be buried will depend on the stress on the cable and the [illegible] of the soil. In ordinary loam, clay, or sand the depth should not be less than 6 feet. Additional bearing power may be given by inserting pieces of plank in front of the deadmen. The cable should

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ROCK LEDGE

[illegible] places the only available an
[illegible] examined before it is used, [illegible]
the texture of the rock no
[illegible] of the ledge measured if p
[illegible] heavy enough, a hole shoul
[illegible] deep and 2 inches in diamet
[illegible] steel, with a split o
[illegible] edge, and an eye with a ship
[illegible] should be sledged into the hole
as far as possible. The rema
[illegible] should be filled with neat
[illegible] pieces before the load is p
[illegible] Babbitt metal, or brimste
[illegible] places these are preferred
[illegible] may be made on top of
[illegible] square made of 1½-inch m
[illegible] be 12 inches and the leng
[illegible] reed, is placed into two ha
[illegible] as described above for th
[illegible] through the U bolt and fa
[illegible] and to protect the cable.
[illegible] them in a triangular
The cable is then run throu

[illegible] AND AFTERWORK.

THE CABLE

[illegible] of six strands, each
[illegible] a hemp center. The materi
[illegible] The cable should be galva
[illegible] no splicing being allowed,
[illegible] the factory, as few dealer
[illegible] in stock.
[illegible] regarded as standard 1 inch
[illegible] cable for spans between 400
[illegible] for each span must be deter
[illegible] III, in order not to exceed the

[illegible] show functions of other than
[illegible] ether with Plate IIII, cro

[illegible] cable are based upon the
Engineering News, May 6, 19

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TABLE 22.—Bill of material for [illegible] cross-[illegible]

[illegible]	No. of pieces.	Size of timber.	Size of iron [illegible]
[illegible]	2	4 by 10 inches by 12 feet 6 inches	1 by 10 inches by [illegible] inches.
[illegible]	2	6 by 6 inches by 22 feet	4 by 10 inches by [illegible]
[illegible]	2	3 by 6 inches by 10 feet 9 inches	3 by 6 inches by [illegible]
[illegible]	2	3 by 6 inches by 9 feet 4 inches	3 by 6 inches by [illegible]
[illegible]	1	3 by 6 inches by 6 feet	3 by 6 inches by [illegible]
[illegible]	1	3 by 6 inches by 6 feet 3 inches	3 by 6 inches by [illegible]
[illegible]	1	3 by 6 inches by 2 feet 7 inches	3 by 6 inches by [illegible]
[illegible]	1	3 by 6 inches by 2 feet 7 inches	3 by 6 inches by [illegible]
[illegible]	2	3 by 8 inches by 1 foot	3 by 8 inches by 1 foot.
[illegible]	4	3 by 8 inches by 1 foot 6 inches	3 by 8 inches by 1 foot.
[illegible]	2	3 by 4 inches by 10 feet	3 by 8 inches by 10 feet.
[illegible]	17	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot.
[illegible]		1 adhesive contraplate with eyebolt, nut, and eye washer	1 by 2 inches by 1 foot.
[illegible]	4	See Plate XXVIII	See Plate XXVIII.
[illegible]	1	See Table 17	See Table 7.
[illegible]	2	do	Do.
[illegible]	×2	do	Do.
[illegible]	×6	8 by 10½ inches	8 by 10½ inches.
[illegible]	×6	7 by 10½ inches	7 by 10½ inches.
[illegible]	×2	7 by 12½ inches	7 by 12½ inches.
[illegible]	×2	7 by 20½ inches	7 by 20½ inches.
[illegible]	×1	7 by 24 inches	7 by 22½ inches.
[illegible]	6	7 by 8 inches	7 by 8 inches.
[illegible]	×1	1 inch by same length as remaining bolt, with nut and washer	1 by 8 inches.
[illegible]		vanized yoxey chain.	
[illegible]	×4	1 by 7 inches	1 by 7 inches.
[illegible]		5 gallons	5 gallons.

[illegible] eye washers. These are approximately three-fourths inch thick, [illegible] is allowed for in billing the bolt. Use 1 flat washer on south leg screw [illegible]

[illegible] dogs are used omit all holder irons and make pocket bolts of 4 inches diameter.

ANCHORAGES.

COMMON TYPES

[illegible] usual types of anchorages for cables are deadmen, [illegible] [illegible]ges. Designs of timber and concrete deadmen [illegible] [illegible]X. The anchorages should always be so placed [illegible] [illegible]lly inspected. A station record showing the [illegible] [illegible]atures, and date of installation of anchorages [illegible] [illegible]ber deadmen should be thoroughly inspected at [illegible] [illegible]rs to determine the condition of the timber.

DEADMEN.

[illegible]ber for deadmen should be carefully selected. [illegible] [illegible]ension timber should be used. All timber should [illegible] [illegible], and cleaned of all bark and foreign matter. [illegible] [illegible]osite should be used as a preservative; if neither [illegible] [illegible]mber may be charred.

[illegible] deadmen should be less than 12 inches in diameter [illegible] [illegible] long. All deadmen should be so constructed as [illegible] [illegible]g factor of safety. The length of the stick and the depth [illegible] [illegible] should be buried will depend on the stress on the cable [illegible] [illegible]ture of the soil. In ordinary loam, clay, or sand the depth [illegible] [illegible] not be less than 6 feet. Additional bearing power may be [illegible] [illegible] inserting pieces of plank in front of the deadmen. The cable [illegible]

ROCK ANCHORS

Rock anchors in many places the only available an
anchor must be carefully examined before it is used, t
cleavage or faults, the texture of the rock not
the size of the anchor measured if p
sufficiently durable and heavy enough, a hole should
from one foot 24 inches long and 2 inches in diameter
the shaft is made of ½-inch steel, with a split or
provided with a steel wedge, and an eye with a ship-
thereof. The hole should be dredged into the hole
be remade the split as far as possible. The remai
of the hole should be filled with neat P
ground to one foot or more before the load is put
lead, Bulldog metal, or brimstone
Bulldog. In many places these are preferred to
A very secure anchorage may be made on top of a
the rock cement into square, made of ½-inch round
ground the hole should be 12 inches and the length
more. The hole, secured, is placed into two holes
with the hole as described above for the eye
hole should be made through the U bolt and fastened
the cable being used to power the cable. Thro
hole should be arranged that in a triangular positi
gin mounted over. The hole is then run through the
anchorage for cable clip.

CABLE OR STRAND

STRAND

The cable should be composed of six strands, each strand
of seven wires twisted in long spins. The material should
be galvanized steel. The cable should be galvanized, and
be one continuous piece, no splicing being allowed. As a
cable should be carried from the factory, so the holders carry
cable should be carried.

The size of cable are specified as standard ½-inch cables for
spans of 600 feet, which allow a space between 400 and 600 feet.
The proper length of the cable must be determined from
anchorage. The LIII is a chart to be used, the standard
spans to be made.

Table 5, 6, 7, 8 are for lengths of other than standard
of cable. The spans and the LIII, cover the range
other spans.

The calculations for cable are based upon the method pub
by J. C. Stevens in Engineering News, May 6, 1909. A wo

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TABLE 2.—Bill of material for 24-foot frame—Continued.

[illegible]	No. of pieces.	6 by 6 inch posts.	6 by 10 inch posts.
	1	6 by 10 inches by 12 feet 6 inches	6 by 10 inches by 12 feet 6 inches.
[illegible]	2	6 by 6 inches by 22 feet	6 by 10 inches by 22 feet.
[illegible]	2	3 by 6 inches by 10 feet 6 inches	3 by 6 inches by 10 feet 6 inches.
[illegible]	2	3 by 6 inches by 9 feet 6 inches	3 by 6 inches by 9 feet 6 inches.
	1	3 by 6 inches by 9 feet 6 inches	3 by 6 inches by 9 feet 6 inches.
	1	3 by 6 inches by 6 feet 7 inches	3 by 6 inches by 6 feet 7 inches.
	1	3 by 6 inches by 2 feet 7 inches	3 by 6 inches by 2 feet 7 inches.
	1	3 by 6 inches by 2 feet 7 inches	3 by 6 inches by 2 feet 7 inches.
	2	3 by 6 inches by 2 feet	3 by 6 inches by 2 feet.
[illegible]	4	3 by 6 inches by 1 foot 6 inches	3 by 6 inches by 1 foot 6 inches.
[illegible]	2	3 by 6 inches by 10 feet	3 by 6 inches by 10 feet.
[illegible]	17	3½ by 3 inches by 1 foot 6 inches	3½ by 3 inches by 1 foot 6 inches.
[illegible]			
[illegible]	4	See Plate XXVIII	See Plate XXVIII.
[illegible]	1	See Plate 17	See Plate 17.
[illegible]	3	do	do.
[illegible]	*2	do	do.
[illegible]	*6	3 by 3½ inches	3 by 3½ inches.
[illegible]	*6	3 by 3½ inches	3 by 3½ inches.
[illegible]	*2	3 by 3½ inches	3 by 3½ inches.
[illegible]	*2	3 by 3½ inches	3 by 3½ inches.
[illegible]	*1	3 by 3½ inches	3 by 3½ inches.
[illegible]	4	3 by 6 inches	3 by 6 inches.
[illegible]	*1	3 inch by nineteen-foot-six-inch [illegible]	3 inches.
[illegible]	*4	3 by 7 inches	3 by 7 inches.
[illegible]		3 gallons	3 gallons.

[illegible] are open washers. There are approximately [illegible] washers [illegible] is allowed for in billing the bolt. The 1 flat washer on each lag screw and 2 [illegible]

[illegible] are used much all bolt holes [illegible] and make good bearing [illegible]

ANCHORAGES.

COMMON TYPES.

[illegible] usual types of anchorages for cables are deadmen, trees, [illegible]ges. Designs of timber and concrete deadmen are shown [illegible] XXX. The anchorages should always be so placed that they [illegible]ily inspected. A station record showing the type, con[illegible] features, and date of installation of anchorages should be [illegible] Timber deadmen should be thoroughly inspected at least once [illegible] years to determine the condition of the timber.

TIMBER.

[illegible] timber for deadmen should be carefully selected. Logs rather [illegible] sound timber should be used. All timber should be sound, [illegible] and dressed of all bark and foreign matter. Creosoted [illegible] should be used as a preservative; if neither is available, [illegible] timber may be charred.

[illegible] deadmen the [illegible]

[illegible] long [illegible] are not less than [illegible] to provide a [illegible] depth to which [illegible] cable and the

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TABLE 26.—*Erection sag (in feet) and tension in erecting cables.*

[Plow-steel rope—6 strands of 7 wires each.]

Span in feet.	Diameter of cable in inches.					
	One-half.		Nine-sixteenths.		Five-eighths.	
	Sag.	*Tension.*	*Sag.*	*Tension.*	*Sag.*	*Tension.*
100	2.86	170	2.04	310	1.45	530
200	6.03	320	4.45	560	3.37	920
300	9.49	460	7.19	780	5.67	1,230
400	13.23	590	10.25	980	8.29	1,490
500	17.26	710	13.58	1,150	11.24	1,720
600	21.53	810	17.20	1,310	14.45	1,930
800	30.86	1,010	25.23	1,590	21.72	2,280
1,000	41.20	1,180	34.28	1,820	30.02	2,580

Span in feet.	Diameter of cable in inches.					
	Three-fourths.		Seven-eighths.		One.	
	Sag.	*Tension.*	*Sag.*	*Tension.*	*Sag.*	*Tension.*
100	0.54	2,060	0.14	10,710	0.12	16,460
200	1.84	2,420	1.11	5,400	.83	9,520
300	3.58	2,800	2.46	5,490	1.92	9,260
400	5.68	3,130	4.20	5,710	3.41	9,270
500	8.09	3,440	6.29	5,960	5.24	9,420
600	10.80	3,710	8.67	6,230	7.38	9,630
800	17.05	4,180	14.27	6,730	12.52	10,100
1,000	24.35	4,570	20.93	7,170	18.70	10,560

TABLE 27.—*Smallest allowable cable, with corresponding sag for various spans.*

Span.	Cable.	Loaded sag.	Erection sag.
		Feet.	*Feet.*
Up to 200 feet	One-half inch	8	6
200 to 300 feet	Nine-sixteenth inch	10	7.2
300 to 400 feet	Five-eighth inch	11.8	8.3
400 to 650 feet	Three-fourths inch	17	12.2
650 to 850 feet	Seven-eighths inch	21.1	15.9
850 to 1,000 feet	One inch	24	18.7

When selecting a cable for a given span, note first the smallest size that may be used, as specified in Table 27. Next find from Plate XXXI or Table 25 the loaded sag and estimate the necessary height of support. It should be noted that for a given span cables other than the smallest size allowable have less sag, so that where it is necessary, as for reducing the height of support, a cable of larger size than the minimum may be used.

TURNBUCKLES.

In order to adjust the cable to the proper sag, a turnbuckle is placed between the deadman and the support. It should be placed close to the ground, so that it may be easily operated.

With cables up to five-eighths inch use a standard 1-inch turnbuckle; with cables between five-eighths and 1 inch use a standard

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1½-inch turnbuckle. A thimble of proper size is used in each eye of the turnbuckle.

The turnbuckles should be of standard manufacture, of round iron, eye and eye, galvanized, and have 36-inch take-ups.

CLIPS.

Three cable clips are applied at each point where the cable is fastened. All clips must be the same size as the cable

BACKSTAY.

A backstay should be run from the top of the support to the anchorage and should be fastened with wire-rope clamps. It is desirable to insert a galvanized eye and eye turnbuckle with 6-inch take-up in the backstay.

For stations using ⅝-inch cables use ¼-inch galvanized wire-strand backstay, with ¼-inch eye and eye turnbuckle; with stations using up to 1-inch cables use galvanized wire-strand backstay half an inch in diameter, with ½-inch galvanized eye and eye turnbuckle. The galvanized wire strand is composed of seven steel wires twisted into a single strand and is commonly used as a guy rope by electric-light companies.

LIST OF MATERIALS.

For each cable station the materials shown in the following table are required:

TABLE 28.—*Bill of material for cable installation.*

—— feet galvanized plow steel cable, —— diameter.
Fourteen cable clips, same size as cable, three at each anchorage, three at each end of turnbuckle, one behind each sheave *S* of support.
—— feet galvanized wire strand, —— diameter.
Eight wire-rope clamps, same diameter as wire strand, one at each anchorage, one at each support, one at each end of turnbuckle.
One galvanized turnbuckle, eye and eye, proper size for cable used.
Two oval wire-rope thimbles, galvanized, same size as cable.
Two galvanized turnbuckles, eye and eye, same size as wire strand.

CARS.

The dimensions of the standard car (Pl. XXIX, *B*) are shown in full detail in Plate XXXII, and a complete list of the material for its construction is given in Table 29. The frame and sides of the car may be made of any suitable lumber, the pieces preferably being fastened together with screws. The appearance of the finished car is shown in Plate XXIX, *B*.

The frame of the car should be given two coats of good paint, one before and one after assembling. A high-grade gray paint may be made by mixing white lead and boiled linseed oil and adding 1 part

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of mixed coach black to 8 parts of mixed lead and oil. Carb (applied hot) instead of paint makes a very satisfactory finis

The marker *T*, which may be made of a piece of lath o wood, is attached to the spacing bar *G* exactly 5 feet from over the side sheave *K*, so that in connection with marking cable the measuring section may be readily located.

A scale of ¾-inch by 2-inch material, long enough to r tween the seats and properly graduated, should be fastene top of the frame *A* as an aid in sounding. A suitable cleat snub should be provided to hold the meter in a fixed positio

A shelter over the car for the protection of the hydrographe rain has been used in Hawaii. This shelter is made of a rubberoid roofing resting on the bar *G*, to which it is tac spread beyond the sides of the car by two wooden spreaders material nailed to the separators *H*.

A notebook rest or table may be attached to the top and o the right-hand side board of the car, as used, at a convenient in front of the main hanger. It should be attached by me pair of 3-inch strap hinges and two screw hooks and eyes, wh it in position for use. When not in use, the hook is released table folds down over the outside of the car. A steel pa screwed to the top of the table holds the notebook while th urement is being made.

All ironwork on the car must be galvanized.

TABLE 29.—*Bill of material for standard cable car.*

[Lettered items refer to Plate XXXII.]

LUMBER.

Item 1. One piece 2 by 4 inches by 18 feet (12 feet b. m.) S 4 S, from whic
Two pieces *A*, sides of bed frame, 6 feet long.
Two pieces *B*, ends of bed frame, 1 foot 7 inches long.
One piece *F*, foot rest, 2 feet 2 inches long.

2. Two pieces 1 by 10 inches by 10 feet (17 feet b. m.), S 4 S, from whic
Two pieces *C*, sides of car, 6 feet long.
Two pieces *D*, ends of car, 2 feet long.
Two pieces *E*1, seats of car, 1 foot 10 inches long.

3. One piece 1 by 8 inches by 16 feet (11 feet b. m.), S 4 S, from which c
Two pieces *E*2, bottom of tool box, 2 feet long.
Two pieces *E*3, seats, 1 foot 10 inches long.
Two pieces *E*4, bottom of tool box, 2 feet long.
Two pieces *E*5, front of tool box, 1 foot 7 inches long.

4. One piece 2 by 2 inches (exact) by 8 feet 3 inches, S 4 S, from which c
One piece *G*, top spacing bar, 7 feet 7 inches long.
Two pieces *H*, spacing blocks, 4 inches long.

5. One-half gallon of gray mixed paint.

HARDWARE.

Item 6. Two cast-iron roller-bearing, spoked sheaves *I*, 8-inch diameter for 1½ cable, with pins *M*, of proper length and diameter, cotter pin in one and two washers for each pin, as per detail.

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Item 7. Two cast-iron roller-bearing, spoked sheaves *K*, 4-inch diameter, for ¼-inch cable, with machine bolts *R*, of proper size and length for pins, and three washers for each pin, as per detail.
8. Two main hangers *L*, as per detail, galvanized.
9. Six machine bolts *N*, ⅜ by 3 inches, for spacers, with nuts.
10. Eight machine bolts *O*, ⅜ by 1¾ inches, in main hanger, eight nuts and eight washers.
11. Two foot-rest hangers *V*, as per detail, galvanized.
12. Eight machine bolts *P*, ⅜ by 4 inches, in foot-rest hanger.
13. Two carriage bolts *Q*, ⅜ by 2½ inches, in foot-rest hanger.
14. Two sheave brackets *W*, as per detail, galvanized, for meter cord sheave.
15. Two swing bolts *U*, 7 inches, galvanized.
16. Four T hinges *XI*, 3 inches, for seat boxes.
17. One gross 2-inch No. 10 F. H. bright wood screws.
18. Two feet gage chain for stop.
19. One standard car puller *PC*.
20. Cleats or cable snub for meter cable.
21. One standard United States Geological Survey padlock.

NOTE.—Sheaves and other parts to be from standard stock as far as practical.

ERECTION.

The design of the cable equipment having been determined and the material assembled, the erection of the cable structure should proceed about as described below. The anchorages should be completed first and the supports and car constructed next. Then the cable should be attached to the anchorage on the side of the stream least accessible, threaded through the sheaves of the first support, stretched across the stream, threaded through the sheaves of the car and second support, the turnbuckle inserted and attachment to the second anchorage made. The supports should then be raised and and the cable set to the proper sag, a differential block generally being used.

The cable may be stretched across the stream most easily by first stringing a No. 10 wire and securing it to each bank. . Then the cable is hung on the wire with carrier hooks, such as are used for carrying lead telephone cables, and drawn across the stream. On streams of moderate velocity, where a boat may be used, the end of the cable may be fastened to the boat and thus kept off the bottom while the boat is pulled across the stream by means of a rope or wire.

On a stream with smooth bottom the cable may be run across the stream in the following manner: Stretch an ordinary telephone wire, of a length at least three times the width of the stream, along the bank at the water's edge, and upstream from the cable site. The upper end should be fastened or held by an assistant and the lower end fastened to a 2 by 6 inch timber 14 to 16 feet long. The timber should be fastened with a yoke to the wire so that it will float at a decided angle to the current. Another wire, long enough to reach well across the stream, should be fastened to the timber at the cable

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site, the timber set afloat, and the wire paid out as the timber travels across the stream, swinging in an arc around the point where the long wire is fastened or held. With this line a larger line, or rope, may be brought across with which in turn the cable may be pulled across.

The desired sag should be obtained by using a level at a proper distance below the top of the sheave block of one support and setting the lowest point of the cable up to this elevation. With favorable topography a wye level set on the side hill may be used. Otherwise an observer with a hand level is placed on the support with his eye at the proper distance below the sheave.

To detect the possible slipping of the cable clips the clip nearest the end of the cable should be so placed that the cable between it and the next clip back is sufficiently slack to give the effect of a slight loop.

The following list will be found helpful in collecting the tools necessary for the erection of the cable stations and standard shelters. Ordinarily it will be advantageous to fit out a box for the tools, which may then be shipped to the site of the work. The box should contain the following:

TABLE 30.—*Tools for field use.*

CARPENTER'S TOOLS.

Squares: 24-inch steel; 6-inch try; 6-inch bevel.
Level: 3-foot spirit.
Rule: 6-foot folding.
Handsaws: 24-inch crosscut, 26-inch rip, teeth of both with wide set.
Wood chisels: Six of different widths.
Hand ax: One 3-pound with nail puller.
Hammer: One good claw hammer.
Screw driver: 8-inch medium; also bits for brace.
Bit brace: One ratchet, 10-inch swing.
Bits: Auger, twist, chain-drill attachment. Include one $\frac{3}{8}$ by 10 inch, one $\frac{5}{8}$ by 14 inch, one $\frac{13}{16}$ by 16 inch.
Files: Six, assorted size and shapes.
Bar: One pinch bar with claw.

MASON'S TOOLS.

Trowel: 10-inch brick trowel.
Hammer: Stonemason's, $3\frac{1}{2}$ pounds, with short handle; 8-pound striking hammer.
Drills: Four diamond point or star point, $\frac{1}{2}$ inch by 2 feet; three diamond point, $1\frac{1}{2}$ inches by 3 feet; one diamond point, $\frac{3}{4}$ inch by 2 feet.

OTHER TOOLS.

Pliers: One lineman's 10-inch; one pair combination.
Cold chisel: One 6-inch.
Wrenches: 6 and 12 inch monkey; 8, 14, and 24 inch Stillson.
Extras: Extra nuts and washers of assorted sizes; extra cable clips.
Picks: Ordinary and grub, if necessary.
Shovels: Short and long handle, as required.

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TACKLE.

Differential: 5-ton differential block.
Chain: One length log chain 12 feet; one length cable chain 12 feet.
Rope: 1-inch manila, 50 feet; ½-inch manila, 100 feet, with steel tackle blocks.

SUNDRIES.

Pails: One water and two bailing pails.
Pump: Diaphragm operated by gasoline engine, where required.

BRIDGES.

A gaging station established at a place where a stream is crossed by a bridge can generally be installed at a cost lower than that involved in any other installation. Unfortunately the conditions of channel and current that insure accurate records are not always found at existing bridges, so that the saving of expense generally involves the sacrifice of accuracy, which is more surely attained by selecting a site without reference to existing structures. Even if the first cost of a cable station is larger, it will be justified by the material saving that will be effected in maintenance, if the station is to be continued through a considerable period of time, because fewer discharge measurements will be necessary to determine the station rating curve.

If the stream is not too large it may sometimes be advantageous to construct a special wooden or suspension bridge.

The type of wooden footbridge shown in Plate XXXIII may be used on spans up to 80 feet. It is made up of two main stringers *E*, spliced if necessary, and trussed with ¾-inch steel rods. The struts *F* are braced crosswise by the braces *C* and lengthwise by braces *K*. On the inside of each stringer *E* is spiked a batten *G*, 1 by 2 inches, upon which rests the 2 by 4 inch floor beams *B*, spaced 4 feet on centers. Tie-rods *T*, ⅝ inch in diameter, pierce the stringers *E* close to the floor beams *B*, which they hold securely in place. Under the ends of the floor planks 4 by 4 inch beams *J* replace the intermediate beams *B*. Suitable sills *S* are placed under each end of the bridge.

The structure should be painted with standard gray paint. The bill of material shown in Table 31 is for a bridge 60 feet long; for any other length it should be revised accordingly.

TABLE 31.—*Bill of material for standard footbridge.*

[Lettered items refer to Plate XXXIII.]

LUMBER.

Item 1. Six pieces *E*, stringers, 6 by 8 inches by 24 feet long (576 feet b. m.).
2. Two pieces 6 by 6 inches by 16 feet (96 feet b. m.), from which cut—
Four pieces *F*, posts, 2 feet 9 inches long.
Two pieces *H*, braces, 2 feet long.
Two pieces *S*, sills, 6 feet 6 inches long.

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Item 3. Four pieces *A*, floor planks, 2 by 12 inches by 16 feet lo
4. Five pieces 2 by 4 inches by 16 feet (55 feet b. m.), from
Thirteen pieces *B*, floor beams, 2 feet long.
Four pieces *C*, braces, 3 feet 8 inches long.
Four pieces *K*, braces, 7 feet 8 inches long.
5. One piece 4 by 4 inches by 10 feet (14 feet b. m.), from whic
J, floor beams under joints, 2 feet long.
6. Ten pieces 1 by 2 inches by 12 feet (20 feet b. m.), battens,

HARDWARE.

Item 7. Four pieces flat steel, 6 by 6 inches by ½ inch, bearing plates
hole drilled in center.
8. Sixteen machine bolts *D*, ¾ by 8 inches, for splices.
9. Thirty-two ogee cast-iron washers, ¾ inch, for bolts *D*.
10. Sixteen steel tie-rods *T*, ⅝ inch by 3 feet 3 inches long, with a
each end and two nuts each.
11. Thirty-two ogee cast-iron washers, ⅝ inch, for rods *T*.
12. Four steel rods, ¾ inch, for lower chords, 30 feet 3 inches long
both ends, with one nut and one ogee cast-iron washer each.

Streams less than 200 feet wide may be spanned by f constructed on supporting cables of ⅜-inch galvanized p or of cables built up of a sufficient number of parallel s No. 10 galvanized-iron wire. When a suspension cable of t type is used, it should be built up by passing separate across the stream and fastening them in place, the wire being u from the coil as used.

Two suspension cables should be carried over the stream same elevation and 3 feet apart. They should be supported b or A frames if necessary, and the ends should be fastened ei trees or deadmen. Directly over and 3 feet above the main there should be two cables to serve as guards and to furnish su and stiffness to the bridge. Each of these cables should be conn vertically with the corresponding lower cable by means of N wire, or by seizing wire which, being drawn taut, transmits a po of the load to the upper cable. These verticals should be put i the end of each 2 by 4 inch by 3-foot 6-inch floor beam.

The floor beams should be placed 4 feet apart along the lo cable with the 4-inch dimension vertical. They should be notch 1 inch deep 3 inches back from each end. The notches, togeth with the vertical connecting wires wound around the crosspiec and the cable at each end, will prevent the crosspieces slipping fro the cable.

The floor may be made of two parallel lines of 1 by 8 inch boards spaced 2 inches apart. Either 12-foot or 16-foot boards should be used, and so laid as to break joints at the ends. The floor boards should be nailed to the 2 by 4 inch floor beams by 2½-inch (8d.) nails.

Measuring points should be marked on the bridge floor and the distance from the initial point should be painted beside the marks.

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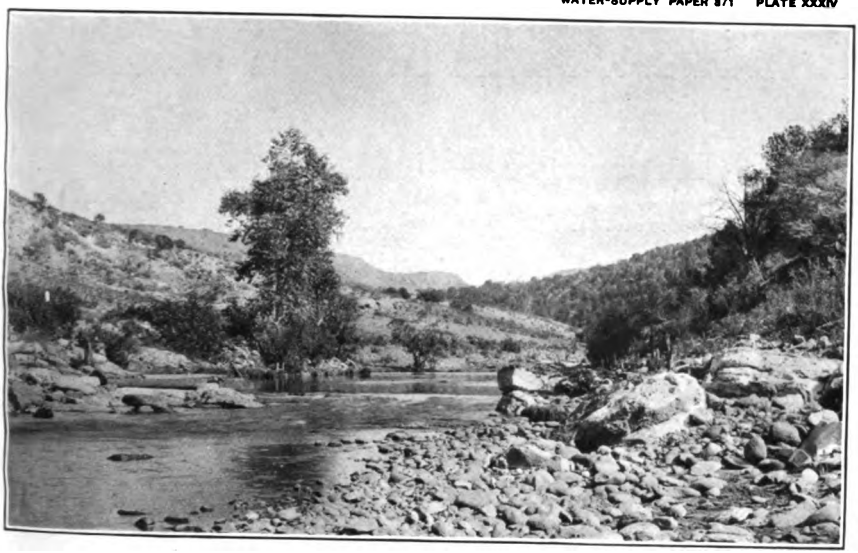
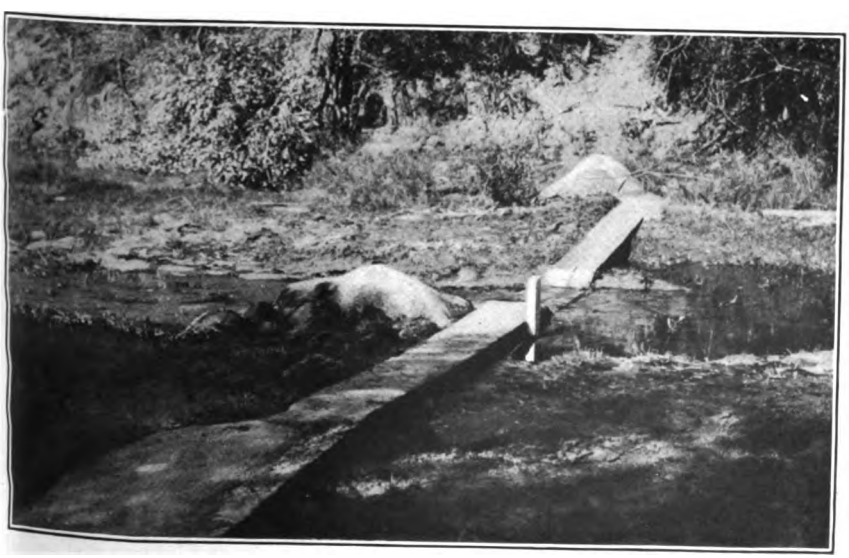


A. EXCELLENT NATURAL CONTROL.

Black River at Fort Apache, Ariz.



B. ARTIFICIAL CONTROL.

Sweetwater River at Descanso, Cal.

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BOATS.

Boat stations as ordinarily equipped are unsatisfactory because of the difficulty in holding the boat in position while making soundings and in operating the meter, but ferryboats operated from cables can often be used advantageously.

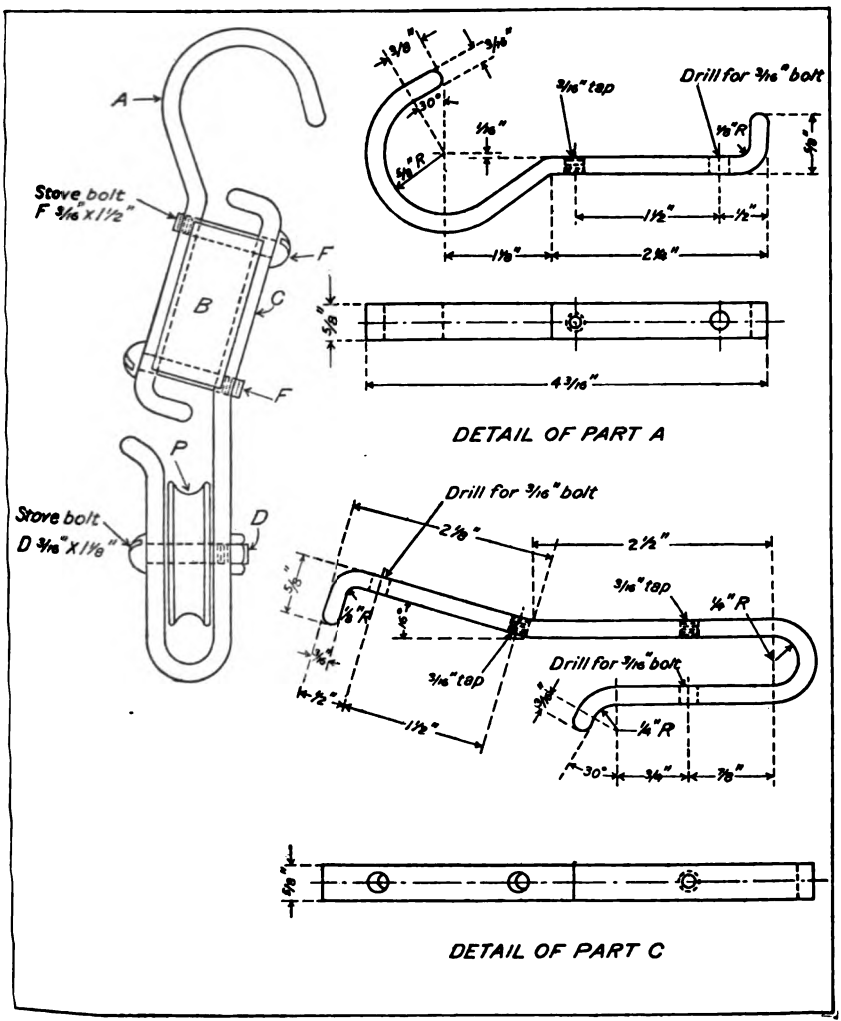

FIGURE 10.—Plans for trolley for use with ferryboats.

In making measurements by this method it is necessary to keep the meter beyond the influence of the boat on the stream. For this purpose the trolley shown in figure 10 is useful. A pole 2 inches in diameter about 10 feet long is squared off at one end and inserted between the pieces *A* and *C*, which are of medium hard brass. These

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are clamped to the pole by means of the stove bolts *F*. T part *A* is hung over the ferry cable, and the meter cord over the pulley *P*, the trolley being pushed ahead of the measurement progresses.

In measuring large streams, such as Niagara, St. Law Mississippi rivers, specially constructed and equipped c have been used with great success by the Corps of Engin United States Army, but the equipment is expensive a practically restricted to special investigations on important

TABLE 32.—*Bill of material for ferry cable trolley.*

Item 1. One piece each of medium hard brass, *A* and *C*, dimensions show 10, drilled and tapped as shown.
One round-head stove bolt *D*, $\frac{5}{16}$ by $1\frac{1}{2}$ inches.
Two round-head stove bolts *F*, $\frac{5}{16}$ by $1\frac{1}{2}$ inches.
One pulley *P*, $1\frac{1}{4}$ inches diameter.
One pole *B*, at least 10 feet long, to be kept at the ferry station.

STAY LINES.

A stay line to hold the meter vertical against the drag current is a desirable adjunct to a current-meter station. T of the stay line is illustrated in Plate V, *A* (p. 15). Stay lines be fastened to trees or to posts set firmly in the ground and pr guyed. A galvanized eye and eye turnbuckle should be in at one end of the line to take up the sag.

The stay line should be placed so far upstream from the that the line from meter to stay line makes an angle of not than 30° with the horizontal. Half of the distance between the line and car may be covered by a No. 10 galvanized wire, one en which should be attached to a $2\frac{1}{2}$-inch clothesline pulley rolling the stay line, the end nearest the car being attached to a 2-inch g vanized awning pulley that will accommodate $\frac{3}{8}$-inch braided s cord.

The following table will aid in the selection of stay lines:

TABLE 33.—*Data for selection of stay lines.*

Span.	Stay line.	Breaking strength.	Minimum sag.	Turnbuckle.	Fastening.
		Pounds.	*Feet.*		
Up to 200 feet..	No. 8 galvanized telegraph wire...	1,000	2	One-fourth inch...	Twisted.
200 to 500 feet..	One-fourth inch standard steel wire strand.	2,300	7	.....do.....	Wire clamps.
500 to 750 feet..	One-half inch high strength (crucible steel), wire strand.	18,000	8	Five-eighths inch.	Do.
750 to 1,000 feet.	One-half inch extra high strength (plow steel) wire strand.	27,000	15	Seven-eighths inch.	Do.

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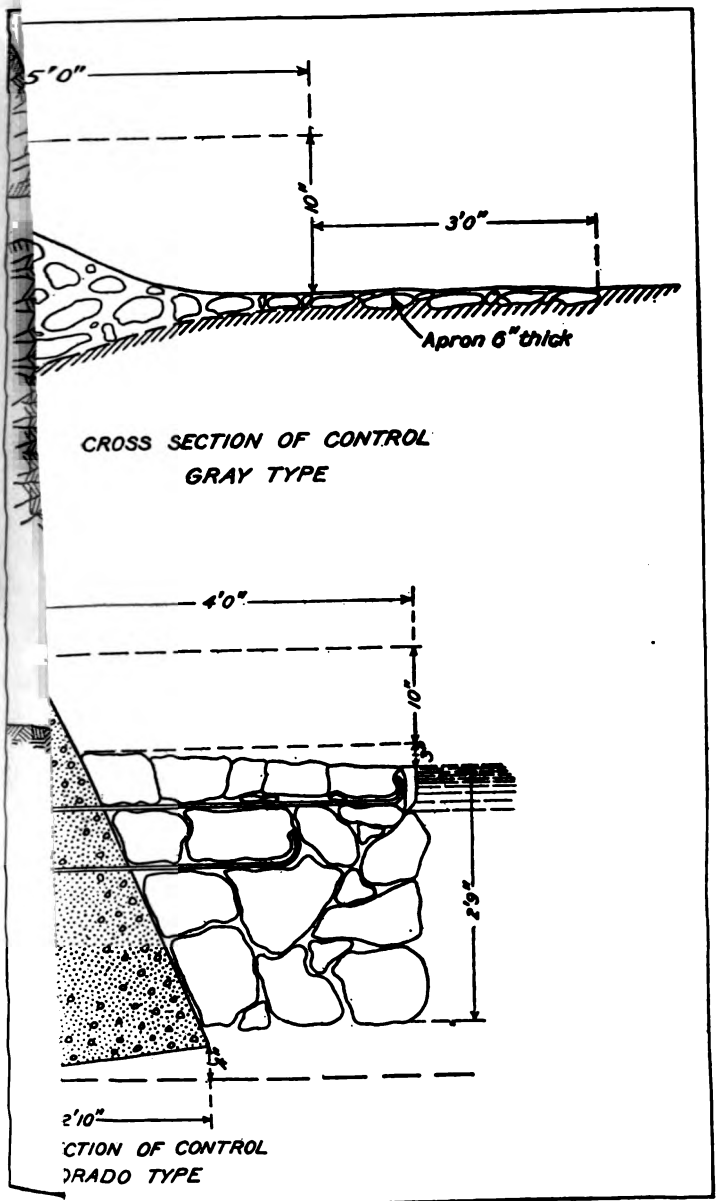

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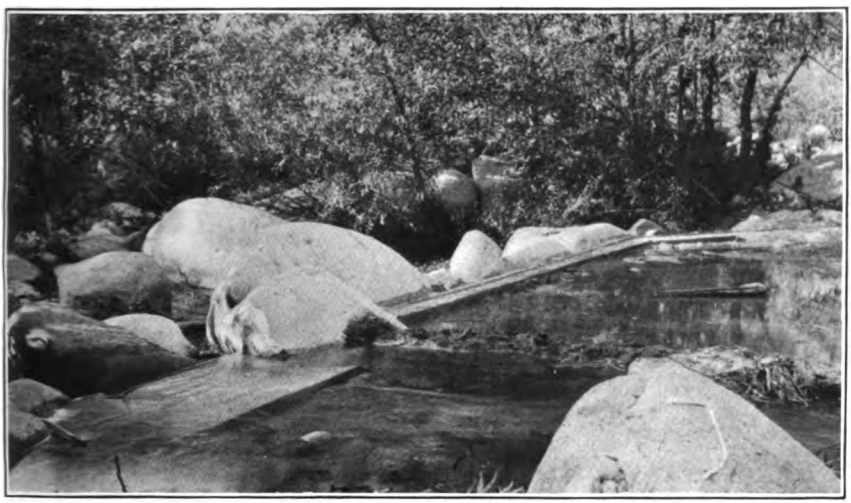

A. SAN LUIS REY RIVER AT PALA, CAL.

B. LOGAN RIVER AT LOGAN, UTAH.

ARTIFICIAL CONTROLS.

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LINES FOR INDICATING MEASURING POINTS.

In order that the measuring points at a gaging station may be easily found at the time of making measurements and that the distance between the measuring points may be readily determined, they should be referred to a fixed initial point, and the span should be divided into sections by permanent marks placed at regular intervals on the bridge rail or floor of a bridge station; on the main cable or on a secondary tagged cable of a cable station, or, for measurements made from a boat or by wading, on a tape or tagged line stretched across the stream. If tape or tagged line can not be left in place, the initial point should be so located and marked that at each discharge measurement the line can be stretched in the same position as for previous measurements.

ARTIFICIAL CONTROL.

A permanent control, assuring a constant discharge relation, is one of the essential features in the efficient operation of a current-meter station. At many stations a natural control may be discovered by careful reconnaissance. An especially fine natural control is shown in Plate XXXIV, *A*. At this station a solid rock dike extends entirely across the channel and up on each bank; there is a fall of several tenths of a foot at low water; the rock is smooth; and there is no chance for gravel or silt to deposit behind the control. Such natural controls are, however, exceptional, and on many streams it is impossible to find a control of any kind. This is notably true of most of the streams in southern California and Arizona. The beds of these streams shift greatly during high water, the amount of the change depending rather on the duration of the flood than on its intensity. The changes are greatest in those streams in which the sand and water flow along together all the time, the result being a continually shifting channel. Under such conditions the construction of an artificial control may make it possible to obtain an accurate station discharge curve with a reasonable number of stream measurements.

Artificial controls should be made to conform as nearly as possible to the contour of the stream bed, so that the natural adjustment of the stream to its channel will be disturbed as little as possible. The site should be selected only after careful reconnaissance. Bedrock, either exposed or buried at shallow depth, or a nest of bowlders affords the best anchorage or foundation for the control and the apron which is to receive the overfall. There must be a free fall along the channel below the control in order to prevent the formation of secondary sand controls that would destroy the effectiveness of the structure. The velocity over the control should be sufficient

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DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 372

A WATER-POWER RECONNAISSANCE IN SOUTH-CENTRAL ALASKA

BY

C. E. ELLSWORTH AND R. W. DAVENPORT

WITH

A SECTION ON SOUTHEASTERN ALASKA

BY

J. C. HOYT

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1915

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PREFACE.

By Alfred H. Brooks.

A study of the water supply of parts of Alaska has been carried on by the United States Geological Survey for several years. At first the work was confined to Seward Peninsula; later it was extended to the Yukon-Tanana region. In each of the most important mining districts of these two provinces stream gaging records were obtained covering three to five years, and the results have been published in summary form.[1] It is unfortunate that the demands of other investigations have not permitted the allotment of additional funds for the continuation of this work to the end that longer records of stream flow might be obtained and other inland districts examined.

This volume is devoted to water investigations in another field. The rapid development in the region tributary to Copper River, Prince William Sound, and the lower Susitna has led to much search for water powers, and for this reason a preliminary examination of the province was undertaken in 1913. Measurements of stream volumes made during only one season can not, of course, be relied upon for estimating average flows, but this study has yielded much information on the topography of drainage basins, reservoirs, and power sites, and incidentally water measurements were made. These field data, together with compilations of the Weather Bureau's records of precipitation, are here brought together in convenient form and will, it is believed, serve as a general guide to the engineer, who will be the first to realize that it must be supplemented by surveys and measurements before any water-power project is seriously considered. This volume will at least serve to show that water powers available throughout the year are not so abundant in this part of Alaska as has sometimes been assumed.

The general province here discussed contains valuable mineral deposits. In its eastern part lies the Bering River coal field, with its high-grade fuels, and also the Katalla oil field. In the Copper River basin and in the Prince William Sound region, to the west, there are

[1] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula: U. S. Geol. Survey Water-Supply Paper 314, 1912. Ellsworth, C. E., and Davenport, R. W., The surface water supply of the Yukon-Tanana region: U. S. Geol. Survey Water-Supply Paper 342, 1914.

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valuable gold and copper deposits. The gold deposits of the Willow Creek district of the Kenai Peninsula also lie in the province investigated, and the Matanuska coal field, with its valuable fuels, is close at hand. Take it all in all, this is one of the richest mineral districts in Alaska and it contains also arable lands. Moreover, it embraces two of the most important gateways into inland Alaska—the Copper River and Susitna valleys. Any power development in this field must be undertaken with full recognition of possible competition with the mineral fuels noted above. Coal and oil now command high prices but when the local fields are opened can doubtless be supplied at much lower rates.

This report is essentially the work of Mr. Ellsworth and Mr. Davenport, who deserve great credit for having collected so much information in a single field season in a region which is in large part difficult of access. Appended to the main report is a reprint of an article by John C. Hoyt on the water powers of southeastern Alaska. There is thus brought together all the available information concerning the water powers along the Pacific coast of Alaska as far west as Cook Inlet. These investigations should be followed by studies of stream flow extending through a period of years sufficiently long to afford data for accurate generalizations on stream volume. This work will be begun as soon as circumstances permit. For the present it must be deferred, as the annual grant of funds must be used for what are believed to be more important surveys and investigations.

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A WATER-POWER RECONNAISSANCE IN SOUTH-CENTRAL ALASKA.

By C. E. Ellsworth and R. W. Davenport.

INTRODUCTION.

This report, which presents the results of the first systematic study of the water powers of south-central Alaska, has been compiled from observations made by the writers during the field season beginning May 5, 1913, and ending November 25, 1913, supplemented by information obtained from numerous reports and maps prepared by other members of the Survey and from records furnished by the Weather Bureau.

The areas investigated (see Pl. I) were the Bering River basin in the Controller Bay region; the basin of Lower Copper River and its principal tributary, the Chitina; numerous localities in the Prince William Sound region; the Willow Creek district; and the eastern part of Kenai Peninsula. Most of the larger streams in the vicinity of commercial centers and mining camps were visited, but this report should not be considered a complete inventory of the streams on which power may be developed within the areas discussed.

Southern Alaska is generally understood to afford many opportunities for large water-power development. Its water powers are sometimes spoken of as "unlimited," a term which, of course, is never literally correct as applied to water powers and which is not at all applicable to the area covered by this report. The coastal regions of south-central Alaska are, however, particularly favored with many small undeveloped water powers having capacities of less than 200 or 300 horsepower, and there are perhaps a few sites where plants of 1,000 or 2,000 or possibly as much as 5,000 horsepower could be operated throughout the year.

It is impracticable to estimate even approximately the power that could be continuously developed on many of the streams investigated, for no previous records of flow have been kept on streams in this region, and the data obtained during this reconnaissance represent only that part of the year when the streams are at or above their average stage. Even during that period daily records were

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obtained on only a few streams. It would be necessary to make daily observations for a year at least in order to estimate with reasonable accuracy the mean yearly discharge. Another reason, of nearly equal importance, is the lack of information regarding the capacity of the various reservoir sites. If water power is to be developed continuously throughout the year, the value of storage reservoirs—in which the excess flow in the summer and fall can be conserved for use during the winter—can not be too strongly emphasized.

Willing assistance and information were given to the writers by many residents of the country during the progress of the field work, and it is regretted that individual recognition can not be accorded. For gage readings and special services particular acknowledgment is due to G. L. Banta; the Copper River & Northwestern Railway; W. A. Dickey, manager Three Man Mining Co., of Landlocked Bay; Ellamar Mining Co.; Gold Bullion Mining Co.; Free Gold Mining Co.; S. M. Graff, manager Seward Light & Power Co.; Charles G. Hubbard, manager Kenai Dredging Co.; Kennicott Mines Co.; A. R. Ohman; C. I. Olsen; Herman Schmesar; and L. W. Storm, mining engineer, Valdez.

METHODS OF INVESTIGATION.

The two controlling features of a stream basin with respect to its water power capacity are (1) the run-off and its variation throughout the year and (2) the head under which the water can be utilized at the wheels. A third feature, however, that will frequently determine the practicability of the project on Alaska streams is the storage capacity that can be created above the point of diversion.

To determine the run-off, measurements of discharge were made by a current meter, and where practicable gages were installed from which the elevation of the water surface was read at various intervals of time depending on the proximity of the observer. After measurements of discharge are made at different gage heights, the discharge at any gage height can be estimated by plotting the measurements on cross-section paper, with discharges as abscissas and gage heights as ordinates, and then drawing a curve through the plotted points. A rating table is then prepared showing the discharge for various gage heights, the reliability of which depends on the accuracy of discharge measurements and gage readings, and also on the permanency of the stream channel. Where gage readings are not available the discharge is, of course, unknown except at the time of the engineer's visit, when discharge measurements were made. Such measurements are called miscellaneous and should be used with care in estimating the flow at other times, because of the rapid fluctuation that is characteristic of the streams. As previously

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mentioned, the records do not cover the low-water season which occurs from the late fall until about the first of May.

The head in feet obtainable at the various sites was determined either by aneroid barometer or from the following topographic maps:

Controller Bay region, scale 1:62,500, contour interval 50 feet.
Chitina (reconnaissance), scale 1:250,000, contour interval 200 feet. Published in Bulletin 374.
Nizina district, scale 1:62,500, contour interval 50 feet. Published in Bulletin 448.
Valdez Bay and vicinity, scale 1:62,500, contour interval 50 feet.
Ellamar and vicinity, scale 1:62,500, contour interval 100 feet.
Kenai Peninsula (reconnaissance), scale 1:250,000, contour interval 200 feet.
Willow Creek district, scale 1:62,500, contour interval 100 feet.

It was entirely beyond the scope of this reconnaissance to determine the capacity of the reservoir sites. Lakes that might furnish natural storage were measured on existing maps wherever possible, and the areas of lakes situated in unsurveyed districts were estimated merely by inspection and, of course, statements based on such methods can be considered only roughly approximate. No attempt was made to estimate the capacity of reservoirs that would be created by the construction of dams.

In the course of the reconnaissance the topography and rock formation at the outlet of lakes and other basins where it might be desirable to create storage reservoirs were hastily examined with reference to the possibilities of constructing dams. Distances were measured by pacing where the sites were easily accessible; where not, they were estimated. Elevations were either determined by hand level, aneroid barometer, or by estimation.

Statement of other physical features of the basins, such as forests, glaciers, general topography, and soil covering in this report, are based either on field observations by the writers or on information obtained from reports and maps prepared by other members of the Survey.

DEFINITION OF TERMS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups—(1) those which represent a rate of flow, as second-feet, gallons per minute, miner's inches, and discharge in second-feet per square mile, and (2) those which represent the actual quantity of water, as run-off in depth in inches and acre-feet. The units used in this report are second-feet, second-feet per square mile, run-off depth in inches and acre-feet. They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second and is the unit for the rate of discharge of water flowing in a stream 1 foot

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wide, 1 foot deep, at a rate of 1 foot per second. It is generally used as a fundamental unit from which others are computed by the use of the factors given in the following table of equivalents.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off, depth in inches," is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

An "acre-foot" is equivalent to 43,560 cubic feet and is the quantity required to cover an acre to the depth of 1 foot. The term is commonly used in connection with storage for irrigation work.

In the tables, "accuracy" shows the probable reliability of the record of the mean monthly flow. "A" indicating that the record is probably accurate within 5 per cent; "B," within 10 per cent; "C," within 15 per cent; "D," within 25 per cent. Special conditions are covered by footnotes.

CONVENIENT EQUIVALENTS.

The following is a list of convenient equivalents for use in hydraulic computation:

1 second-foot equals 40 California miner's inches (law of Mar. 23, 1901).
1 second-foot equals 38.4 Colorado miner's inches.
1 second-foot equals 40 Arizona miner's inches.
1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,317 gallons per day.
1 second-foot for one year covers 1 square mile 1.131 feet or 13.572 inches deep.
1 second-foot for one year equals 31,536,000 cubic feet.
1 second-foot for one day equals 86,400 cubic feet.
1,000,000 United States gallons per day equals 1.55 second-feet.
1 acre-foot equals 325,850 gallons.
1 foot equals 0.3048 meter.
1 mile equals 1.60935 kilometers.
1 mile equals 5,280 feet.
1 acre equals 43,560 square feet.
1 acre equals 209 feet square, nearly.
1 cubic foot of water weighs 62.5 pounds.
1 foot head of water equals 0.434 pounds per square inch pressure.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.80 feet.
1⅓ horsepower equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{12.57}$ = net horsepower on water wheel realizing 70 per cent of theoretical power.

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WATER-POWER RIGHTS.

Water-power sites on public lands in Alaska within the national forests are under the jurisdiction of the Department of Agriculture; those outside the national forests are under the jurisdiction of the Department of the Interior. An act of Congress approved February 15, 1901 (31 Stat., 790), provides for permits for rights of way for power plants and transmission lines on the public lands. Regulations concerning the acquisition of rights of way under this act have been issued by both the above departments and can be obtained on application. On the ground of the inapplicability of general land laws to lands in Alaska, a question as to this act was submitted to the Department of Justice, and on June 29, 1915, the Attorney General decided that this act is applicable to Alaska. In national forests in Alaska it has been possible to provide for water-power development through special-use permits under the act of June 4, 1897 (30 Stat., 11), which authorizes the Secretary of Agriculture to regulate the occupancy and use of national forests.

It is believed that the only rights to the use of either land or water for the development of water power in Alaska have been acquired by special-use permits issued by the Secretary of Agriculture, by the posting of a notice of appropriation at the points of diversion and use, or by squatting. In the event of conflicting claims it is presumed that the relative rights of the claimants could be established in court.

CLIMATE.

GENERAL CONDITIONS.

The diversity of the climate of Alaska in its different parts and the consequent widely varying accounts thereof have given rise to much popular misconception. As a basis for the true conception it is necessary to comprehend the extent of the Territory and the many physical influences to which it is subject. The Territory (not including the Aleutian Islands) is limited in longitude by meridians 130° west and 168° west and in latitude by parallels 54° 40′ north and 71° 30′ north. Its southern shores are washed by the warm waters of the Pacific and its northern by the cold waters of the Arctic, which are open to navigation but a small part of the year.

Meteorologic observations in Alaska were undertaken to a limited extent by the Russians. Since the purchase of the Territory by the United States, observations have been made by the United States Army, the Signal Service, regular Weather Bureau observers, and voluntary observers under the supervision of the Weather Bureau and United States Geological Survey. As the Territory has become more thickly settled, the means for obtaining data have increased until at

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the present time the results of a large amount of climatic observations may be found at the United States Weather Bureau, where most of the original records are filed. The records prior to 1878 have been summarized by Dall and Baker [1] and by C. A. Schott.[2] Abbe [3] has treated on the climate of Alaska in a comprehensive manner and has included the records from 1867 to the end of 1902. Henshaw and Parker [4] have summarized the meteorologic data of Seward Peninsula to 1910 and the authors [5] that of the Yukon-Tanana region to 1912.

Abbe, in the report to which reference is made above, divides Alaska into eight climatic provinces, as follows: Pacific coast, Alaska Peninsula, Aleutian Islands, Bering Sea islands, Arctic coast, the interior, and the Copper River Plateau. The boundaries between those provinces do not seem everywhere well defined, and it is probable that as more information becomes available the classification may need revision. The area treated in this report is included in the Pacific coast and Copper River Plateau provinces. Precipitation data are also given for stations on the Alaska Peninsula and the Aleutian Islands.

The Pacific coast province comprises the area extending from Dixon Entrance to Kodiak Island and includes all the islands and the region lying between the ocean and the first range of mountain along the coast from Cross Sound to the beginning of the Alaska Peninsula. Data at hand seem to indicate that the so-called Copper River Plateau province comprises the area bounded on the south by the Chugach Mountains and on the north by the Alaska Range and Nutzotin Mountains. The boundaries of these two provinces are by no means closely defined at all places.

The stations for which data are given in this report are listed in the following table, together with reference numbers by which they may be found on Plate I, their latitude and longitude, and the limiting dates and length of the record.

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[1] Dall, W. H., and Baker, M., Pacific Coast Pilot, Coast and islands of Alaska, Appendix 1, Meteorology and Bibliography, 2d series, Washington, 1879.

[2] Schott, Charles A., Tables, distribution, and variations of the atmospheric temperature in the United States, etc.: Smithsonian Contrib. Knowl., vol. 21, No. 277, pp. 10, 11, 124, Washington, 1876. Tables and results of the precipitation of rain and snow in the United States, etc.: Idem, vol. 24, No. 353, pp. 11, 113, 2d edition, Washington, 1881.

[3] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 133–200, 1906.

[4] Henshaw, F. F., and Parker, G. L., U. S. Geol. Survey Water-Supply Paper 314, pp. 15–32, 1913.

[5] Ellsworth, C. E., and Davenport, R. W., U. S. Geol. Survey Water-Supply Paper 342, pp. 18–41, 1915.

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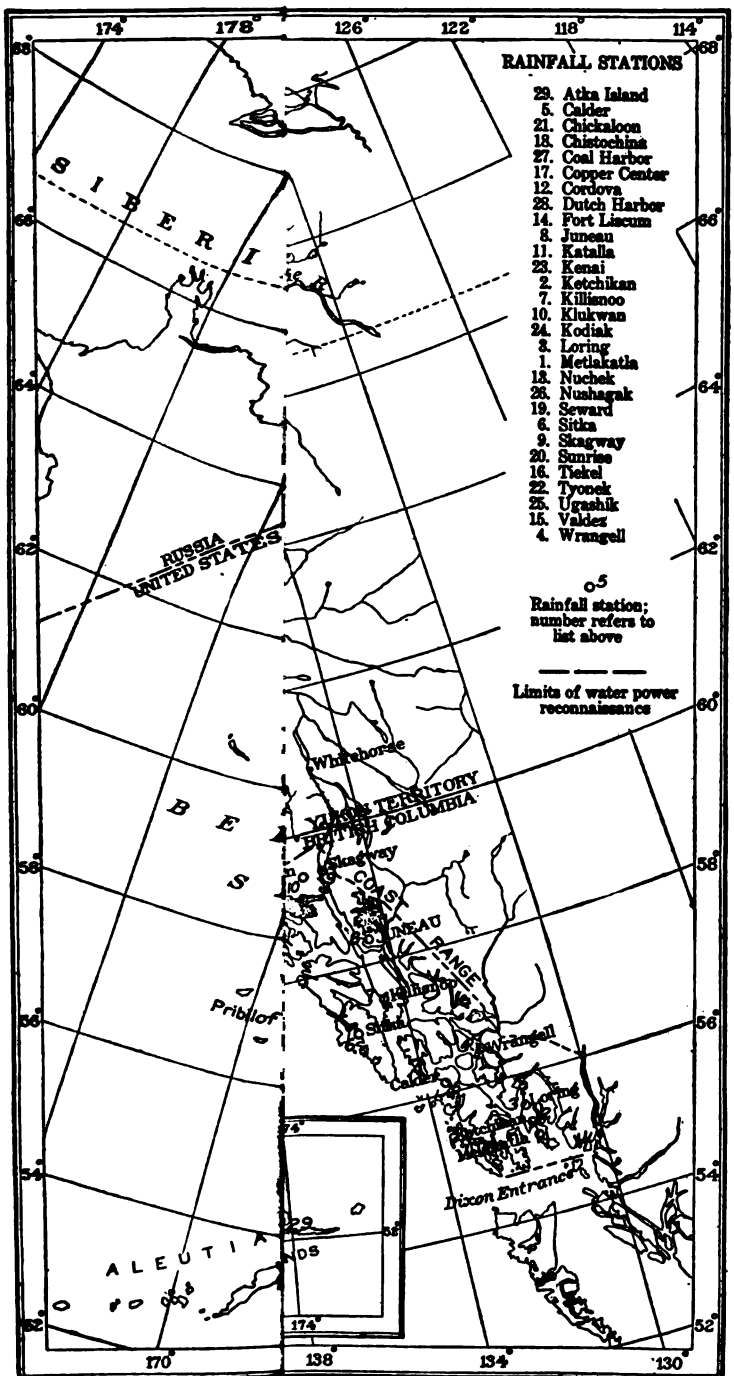

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Location and length of record of Weather Bureau stations in southern Alaska.

No. on Pl. I.	Station.	Latitude.		Longitude.[a]		Length of record.			
						Limiting dates.		Years.[b]	Months.[c]
		°	′	°	′				
29	Atka Island	52	15	174	15	May, 1879	August, 1886	3	14
[d]	Bering Island	52	12	165	55	June, 1882	April, 1886	3	11
5	Calder	56	10	133	28	April, 1908	December, 1913	4	19
21	Chickaloon	61	47	148	30	March, 1910	August, 1911	0	18
18	Chistochina	62	35	144	41	August, 1904	October, 1907	1	21
27	Coal Harbor	55	20	160	38	December, 1893	October, 1909	12	34
17	Copper Center	61	58	145	20	August, 1902	November, 1913	9	25
12	Cordova	60	32	145	46	October, 1899	December, 1913	4	74
28	Dutch Harbor [e]	53	53	166	32	September, 1878	December, 1912	8	65
14	Fort Liscum	61	05	146	20	January, 1901	December, 1913	11	22
8	Juneau	58	19	134	28	July, 1881	November, 1913	12	96
11	Katalla	60	17	144	32	April, 1907	September, 1908	0	18
23	Kenai	60	32	151	19	November, 1882	March, 1908	9	36
2	Ketchikan	55	21	131	39	June, 1902	December, 1913	0	32
7	Killisnoo	57	22	134	29	June, 1881	December, 1910	16	111
10	Kluckwan	59	23	135	54	March, 1908	December, 1913	4	16
24	Kodiak	57	48	152	25	April, 1869	November, 1913	12	140
3	Loring	55	36	131	38	March, 1904	November, 1913	7	32
1	Metlakatla	55	08	131	35	November, 1891	July, 1894	2	9
13	Nuchek	60	23	146	40	May, 1883	August, 1884	0	16
26	Nushagak	58	57	158	21	August, 1881	July, 1905	2	35
19	Seward	60	06	149	27	February, 1908	October, 1913	3	31
6	Sitka	57	03	135	19	May, 1842	December, 1913	42	123
9	Skagway	59	28	135	20	January, 1883	August, 1913	8	95
20	Sunrise	60	53	149	26	October, 1903	November, 1913	7	36
16	Tiekel	61	19	145	21	March, 1904	September, 1907	2	19
22	Tyonek	61	03	151	10	November, 1898	April, 1909	5	44
25	Ugashik	57	35	157	50	January, 1884	December, 1885	2	0
15	Valdez	61	07	146	16	October, 1909	December, 1913	4	3
4	Wrangell	56	28	132	20	June, 1868	January, 1909	0	51

[a] West except on Bering Island, which lies outside the area mapped.
[b] Complete records.
[c] Months of scattered records.
[d] Lies outside of the area mapped.
[e] Records at Udatka and Unalaska combined under Dutch Harbor.

The longest record is that at Sitka, where observations were begun by the Russian Government in March, 1842, and continued until October, 1867. The observatory was on the eastern end of the low, flat Japonski Island. The United States Government has continued the observations since October, 1867, with occasional lapses.

In this report only those aspects of the climate will be considered that bear directly on the water supply. Of those, precipitation and temperature and the agencies which they include are the most important.

PRECIPITATION.

The discharge of streams depends primarily on precipitation, for all water on the earth's surface originally fell as rain or snow. The proportion of the rainfall which passes down the stream, and the sensitiveness of the stream fluctuations to the effect of rainfall depend on other factors. The steep slopes and impervious soil of much of the region along the coast makes this sensitiveness unusually great, and a knowledge of the precipitation along the Alaska coast there-

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fore becomes especially valuable in the absence of actual measurements or as an aid in interpreting stream flow data already obtained.

Most of the important data concerning the precipitation along the Alaska coast are summarized in the following tables, which show the mean monthly precipitation at the various stations, the monthly precipitation at many of these stations since 1900, and the daily precipitation at representative stations for 1913. The annual precipitation at Sitka for the years of complete record is shown graphically in figure 1, and the mean monthly precipitation at all the stations is

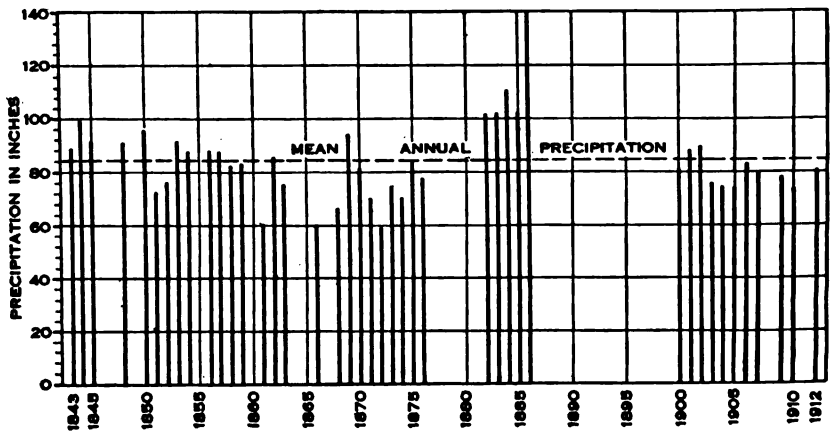

FIGURE 1.—Diagram showing annual precipitation at Sitka, Alaska, 1843–1912.

shown in figure 2. In all these records snowfall is supposed to have been reduced to its equivalent rainfall.

Mean monthly precipitation at Weather Bureau stations in southern Alaska.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Atka Island	9.05	6.47	5.22	6.66	6.55	5.63	5.28	5.67	9.02	10.32	11.59	7.77	89.23
Bering Island	.70	1.59	.91	1.13	.96	1.69	2.46	2.09	2.50	2.60	2.96	1.62	21.21
Calder	8.54	6.59	7.63	8.32	5.57	4.14	5.37	6.38	7.29	16.99	12.18	17.18	106.18
Chickaloon	.84	2.47	.59	.02	.01	.55	1.92	.61	1.46	.07	.03	.05	8.62
Chistochina	.16	.27	.39	0	.16	1.07	2.60	1.82	2.40	1.51	.26	.92	11.56
Coal Harbor	3.72	4.22	3.61	5.56	3.46	2.55	3.31	3.78	4.74	4.80	5.21	4.21	49.27
Copper Center	.57	.46	.17	.07	.39	.86	1.56	1.12	1.13	.96	.70	.75	8.74
Cordova	9.86	9.23	8.82	9.80	9.84	6.67	6.30	11.69	19.91	20.21	11.47	13.97	137.77
Dutch Harbor	10.02	6.81	5.74	5.80	5.42	3.60	2.80	3.26	7.70	10.89	8.74	8.33	79.11
Fort Liscum	7.01	5.08	6.00	3.58	4.12	2.45	5.03	7.83	9.29	9.06	6.01	8.36	73.82
Juneau	6.44	4.41	4.69	4.70	5.31	3.79	4.75	6.86	10.36	9.88	7.55	7.00	75.74
Katalla	11.88	3.94	4.54	7.75	6.30	6.26	11.30	9.67	15.36	25.62	12.44	11.48	126.54
Kenai	.66	.70	.75	.47	.85	.92	2.31	3.61	3.06	2.03	1.07	.87	17.39
Ketchikan	12.48	7.80	12.00	11.99	6.68	5.34	8.98	13.05	14.52	24.80	16.82	19.36	153.82
Killisnoo	4.75	2.14	2.96	3.00	2.80	2.19	3.45	4.21	6.85	7.76	5.64	5.12	50.87
Kluckwan	1.25	1.24	1.32	.55	.73	.89	.68	1.32	3.02	3.60	2.22	2.64	19.46
Kodiak	5.09	4.50	3.73	3.96	5.77	4.45	3.55	4.99	5.71	7.23	6.74	6.76	62.48
Loring	8.26	9.97	10.05	13.07	8.67	6.43	7.54	8.41	17.03	21.03	20.94	16.05	147.45
Metlakatla	12.59	10.48	7.59	6.83	7.32	3.10	6.63	8.12	8.24	15.78	11.23	14.61	132.50
Nuchek	27.07	9.15	18.02	16.92	18.92	4.18	9.93	14.14	22.96	21.50	10.51	16.81	190.11
Nushagak	2.91	1.15	2.53	1.42	2.45	2.10	3.70	4.59	4.82	1.93	2.28	1.20	31.08
Seward	2.01	4.92	3.34	3.70	3.53	1.83	2.66	5.33	7.18	8.62	7.54	8.13	58.79
Sitka	7.65	6.58	5.77	5.54	4.10	3.40	4.29	7.05	10.09	11.84	9.33	8.78	84.42
Skagway	1.68	2.91	1.67	1.39	.79	.94	1.22	1.65	3.08	4.31	4.10	3.51	27.25
Sunrise	2.44	2.70	1.78	2.74	1.95	1.04	2.00	2.98	3.34	4.67	4.30	4.21	34.15
Tiekel	1.28	.84	.95	.36	.36	.92	3.37	1.44	1.11	2.40	3.11	1.88	18.02
Tyonek	1.68	.94	.91	.98	.46	1.05	3.03	5.04	3.43	3.22	1.26	1.21	23.21
Ugashik	1.44	.50	1.04	1.14	1.50	1.14	2.90	3.52	5.52	2.70	1.42	1.62	24.44
Valdez	4.16	6.03	5.49	2.21	3.60	1.75	3.72	4.32	9.08	5.59	2.69	8.99	57.63
Wrangell	5.68	8.11	2.89	4.11	3.58	3.33	3.55	2.97	10.82	8.02	12.92	10.41	76.39

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Mean monthly precipitation at stations in southern Alaska since 1900.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Calder	1908	.....	.....	.....	12.35	5.00	2.77	5.20	6.62	18.83	15.43	11.74	.....	.....
	1909	.....	.....	10.50	3.58	5.01	6.25	10.36	12.68	17.98	16.90	4.77	3.85	.....
	1910	8.35	6.20	9.70	9.20	5.17	4.65	3.75	4.80	7.79	21.35	9.24	14.05	104.25
	1911	10.15	3.00	6.22	8.25	3.23	2.62	2.05	2.70	6.90	10.35	12.55	16.80	84.82
	1912	5.25	11.85	3.30	6.25	6.00	4.23	3.55	4.01	9.80	21.55	14.85	17.72	108.36
	1913	10.40	5.30	8.45	10.30	8.43	4.31	7.30	7.50	20.75	16.35	19.95	15.60	134.64
Chickaloon	1910	.....	.....	.03	.02	.01	1.02	1.42	.05	1.46	.07	.03	.05	.....
	1911	.84	2.47	1.15	.02	.01	.08	2.41	1.17	.....	.....	.....	.....	.....
Chistochina	1904	.....	.....	.....	.....	.....	.....	.....	.40	2.01	.....	.....	.20	.....
	1905	.05	.02	.08	0	.48	.90	3.19	3.20	3.11	1.68	.03	.75	13.49
	1906	.26	.60	.30	Tr.	0	.81	1.78	1.48	.....	.....	.50	1.80	.....
	1907	.....	.20	.80	.....	Tr.	1.50	2.82	2.21	2.07	1.34	.....	.....	.....
Coal Harbor	1901	3.95	6.57	1.99	3.55	.67	2.21	1.64	1.63	2.80	7.45	3.54	8.87	44.87
	1902	6.54	4.64	5.34	4.77	2.98	.33	1.70	3.05	5.88	4.74	6.87	1.20	48.04
	1903	3.90	7.32	1.90	2.26	2.77	2.05	3.66	3.64	5.29	2.52	2.52	4.69	45.52
	1904	2.00	.12	.66	1.89	1.83	1.23	4.22	4.17	3.73	2.07	2.82	2.00	26.74
	1905	.17	9.05	1.20	18.92	6.76	4.44	1.75	2.20	2.95	3.03	9.25	4.64	64.36
	1906	2.33	5.43	6.46	.....	3.27	1.01	3.18	4.28	3.42	4.44	3.52	2.87	.....
	1907	5.65	2.00	1.43	6.72	4.59	1.88	4.71	4.90	5.84	5.83	.....	.....	.....
	1908	6.06	4.49	4.20	1.97	6.47	3.57	3.66	.....	.....	.....	.....	.....	.....
	1909	.....	.....	.....	.....	3.91	1.56	3.08	.....	4.37	1.28	.....	.....	.....
Copper Center.	1902	.....	.....	.....	.....	.....	.....	.....	1.08	.73	2.02	1.50	.20	.....
	1903	.05	.05	.04	Tr.	.60	1.38	.99	1.16	1.34	1.71	.20	.75	8.63
	1904	.67	.22	Tr.	.24	.92	1.11	1.80	2.09	.73	.48	.36	.68	9.30
	1905	.29	1.01	.20	Tr.	.48	.50	1.35	.72	1.94	.97	.94	.97	9.37
	1906	1.14	.19	.69	.36	.43	1.19	2.14	.69	.37	.84	.99	.35	9.38
	1907	.....	.60	.30	0	.36	1.14	.97	.71	.25	1.35	.80	.35	.....
	1908	.45	.25	.05	.10	.13	.27	1.83	.65	.78	1.15	.10	.70	6.46
	1909	.70	.....	.....	.....	.88	.72	3.43	1.27	.52	.40	.20	.60	.....
	1910	1.25	.33	.21	Tr.	Tr.	.48	1.66	.50	.85	1.02	.31	.30	6.91
	1911	.10	1.43	.09	.04	.18	.20	1.12	2.72	1.85	.74	.65	1.94	11.06
	1912	.20	.24	.11	0	.16	1.60	.56	.82	3.79	.65	0	1.61	9.74
	1913	.83	.27	0	0	.15	.89	1.30	.99	1.36	.25	2.35	.55	8.94
Cordova	1901	16.17	1.21	16.91	.....	.....	.....	.....	.....	26.36	24.71	8.02	9.75	.....
	1902	12.02	8.05	.60	.....	.....	.....	.....	.....	.....	35.56	11.10	11.40	.....
	1903	16.74	16.60	.....	.....	.....	.....	.....	10.75	16.67	17.70	13.24	23.44	.....
	1904	11.69	.....	.72	13.55	.....	.....	.....	.....	9.12	27.76	9.66	19.05	.....
	1905	8.20	11.56	12.51	9.10	10.48	6.51	4.42	12.99	.....	15.57	29.64	12.81	.....
	1906	10.63	.94	5.34	7.54	.....	.....	.....	.....	.....	.....	17.08	8.56	.....
	1907	3.26	8.48	2.15	.....	.....	.....	.....	.....	.....	29.15	13.16	15.55	.....
	1908	13.24	13.09	7.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1909	.....	.....	.....	.....	6.09	14.63	4.95	8.86	19.17	9.04	1.69	19.22	.....
	1910	8.89	7.50	16.18	5.34	6.21	5.82	7.51	6.39	12.61	19.70	6.37	9.33	111.85
	1911	4.91	13.69	8.07	14.79	8.42	8.74	4.37	.....	11.27	15.90	9.80	.....	.....
	1912	10.00	12.21	16.79	4.02	20.29	5.66	4.99	23.16	49.63	24.88	5.83	13.47	188.92
	1913	2.68	7.58	3.98	7.72	3.66	.74	12.77	8.46	19.08	15.09	17.19	16.02	114.97
Dutch Harbor.	1906	3.09	9.46	12.19	3.07	6.82	1.14	3.56	3.10	2.29	7.91	5.38	5.76	63.77
	1907	8.76	2.49	2.93	2.97	5.39	1.27	2.11	3.25	.....	7.79	10.82	7.27	.....
	1908	8.01	4.80	1.85	3.87	3.69	2.67	2.71	5.59	6.85	8.40	9.70	8.74	66.88
	1909	5.30	4.60	2.56	3.95	4.20	1.35	1.39	5.33	9.07	20.20	1.59	3.70	63.24
	1910	7.29	4.61	2.39	2.95	6.23	4.18	.46	.....	17.43	11.10	7.86	2.19	.....
	1911	6.88	10.53	4.94	6.10	5.74	.....	5.91	2.92	2.35	8.26	8.56	5.62	.....
	1912	4.20	5.12	8.22	5.74	6.72	4.56	3.70	1.52	6.80	10.82	8.26	4.14	69.80
Fort Liscum.	1901	9.40	.80	6.38	6.20	1.45	1.13	4.77	16.20	12.72	10.31	6.28	7.47	83.11
	1902	9.94	1.28	4.70	2.80	3.08	.24	3.65	8.56	15.72	18.20	6.98	4.43	79.58
	1903	10.42	13.60	4.72	3.87	2.23	3.24	4.29	6.44	8.62	6.62	5.62	9.61	79.28
	1904	6.80	.52	.10	4.50	.68	2.26	5.61	12.45	7.96	9.16	2.20	3.99	56.23
	1905	3.63	5.73	7.17	2.96	7.02	3.83	3.49	9.85	.....	6.06	10.37	7.75	.....
	1906	12.53	1.83	7.54	4.20	1.36	4.01	7.12	8.46	4.11	8.61	7.50	6.75	74.02
	1907	1.75	10.14	6.04	.82	4.05	2.83	11.25	10.61	11.98	16.77	7.94	7.13	91.13
	1908	16.58	7.22	6.58	3.56	.....	.79	2.19	3.35	6.00	8.56	8.72	11.09	.....
	1909	2.29	2.57	5.80	6.94	6.28	6.14	5.78	6.65	6.40	2.83	.59	18.02	70.29
	1910	8.79	6.45	9.80	2.19	5.94	2.68	2.69	4.35	8.90	9.07	1.20	2.93	64.99
	1911	1.98	5.11	4.27	5.08	1.35	2.99	5.60	2.59	5.71	8.01	2.21	6.22	51.12
	1912	2.76	3.93	9.68	.81	5.89	1.01	4.96	6.06	16.64	7.71	6.13	9.75	75.33
	1913	4.26	6.85	5.19	2.57	10.11	.70	4.03	6.19	6.71	5.87	12.37	13.53	78.38
Juneau	1901	9.57	6.32	8.19	8.19	3.47	2.13	1.98	14.04	11.41	16.50	3.52	13.33	98.65
	1902	12.76	2.08	5.64	4.34	3.99	2.41	7.60	12.10	14.24	6.57	7.38	4.26	83.37
	1903	11.31	7.29	3.09	3.74	6.74	1.44	2.26	5.45	6.94	.....	.....	.....	.....
	1904	.....	.....	.....	7.84	6.50	10.40	8.15	4.04	9.20	9.34	8.36	8.80	.....
	1905	2.83	3.08	5.90	4.96	1.58	2.96	1.93	7.85	.....	12.74	15.49	10.32	.....
	1906	4.35	1.57	.56	3.03	.....	1.34	3.58	3.21	3.68	12.30	12.27	2.17	.....
	1907	.48	8.88	2.74	3.10	3.93	2.45	3.40	6.88	17.03	11.19	4.58	.25	66.46
	1908	.39	3.87	6.50	0	4.88	2.45	2.80	3.85	17.00	8.40	1.82	5.32	63.32

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Mean monthly precipitation at stations in southern Alaska since 1900—Continued.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Juneau	1909	.59	3.78	9.22	4.44	5.67	5.77	7.69	11.96	13.68	6.05	2.79	1.97	73.61
	1910	3.08	.88	3.15	4.53	10.17	2.70	9.94	1.55	1.19	2.13	.98	3.58	44.60
	1911	1.34	1.56	1.44	2.51	1.65	2.24	.91	2.20	2.15	7.66	4.09	7.99	35.74
	1912	.54	7.16	2.72	2.93	3.14	5.53	a 3.60	6.50	9.60	14.80	7.94	13.25	.....
	1913	5.21	4.43	4.20	3.67	4.73	.72	6.50	8.39	12.14	14.58	7.76	.....	.....
Katalla	1907	.....	.....	.....	7.50	4.85	8.29	13.96	11.41	12.34	25.62	12.44	11.48	.....
	1908	11.88	3.94	4.54	8.00	7.75	4.22	8.20	7.93	18.38	.....	.....	.....	.....
Kenai	1901	.64	.07	.32	.85	.30	.06	1.66	4.85	2.23	1.69	.64	.19	13.50
	1902	.84	.44	.50	1.03	.42	.59	1.71	2.92	4.69	2.73	.86	1.55	18.28
	1903	.83	2.18	.44	.67	.54	1.16	2.48	3.78	2.72	.77	.78	.18	16.53
	1904	.46	.29	.02	.34	Tr.	.87	2.44	3.50	4.01	1.71	.48	.66	14.78
	1905	.29	.92	.57	.46	.84	.84	1.06	6.26	.78	2.92	2.16	1.41	18.51
	1906	.30	.10	1.24	.17	.29	.57	4.41	2.95	1.41	1.74	.39	1.16	14.73
	1907	.68	.61	.67	.04	1.24	2.31	5.49	.....	10.00	1.66	.....	.....	.....
	1908	.50	.11	.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ketchikan	1910	.....	.....	.....	.....	.....	.....	.....	.....	7.44	28.92	11.88	18.37	.....
	1911	8.51	7.24	8.96	11.99	2.26	6.43	.....	.....	.....	.....	.....	.....	.....
	1912	.....	.....	.....	.....	7.15	6.65	5.60	4.89	16.44	27.78	18.47	21.23	.....
	1913	16.46	8.35	15.04	.....	10.62	4.97	15.73	11.87	19.67	17.69	20.12	18.47	.....
Killisnoo	1901	6.95	6.05	5.40	1.15	4.00	1.60	1.40	5.95	5.50	9.10	3.55	5.30	55.95
	1902	.....	2.65	1.50	2.10	4.70	1.60	3.80	4.80	7.20	4.60	2.75	2.90	.....
	1903	4.05	2.40	.20	6.15	2.55	.75	1.15	2.30	3.10	12.45	3.65	5.00	43.75
	1904	4.30	1.25	1.20	1.35	1.75	3.35	4.60	2.30	7.70	8.20	9.20	8.55	53.75
	1905	1.90	2.80	2.60	2.20	.....	1.20	1.60	4.30	.....	4.10	8.40	7.75	.....
	1906	6.90	2.70	.90	5.15	1.25	2.85	3.80	4.90	4.70	8.40	9.55	2.50	53.60
	1907	1.40	9.55	1.70	1.35	1.60	3.85	3.05	4.65	6.85	8.57	.....	.....	.....
	1908	.....	3.94	.64	2.28	1.55	.97	2.29	2.54	8.95	7.90	6.50	1.86	.....
	1909	1.00	1.80	1.13	.....	.....	.55	3.20	4.50	12.10	7.60	1.35	1.60	.....
	1910	3.50	.81	1.50	1.65	1.20	2.30	4.45	2.15	4.85	8.25	.62	2.35	33.63
Kluckwan	1908	.....	.....	.66	.58	.....	.....	.....	.....	.....	2.38	3.06	1.79	.....
	1909	.20	.35	2.43	Tr.	.79	.92	2.36	1.62	5.24	2.65	.61	1.10	18.27
	1910	1.75	.81	3.13	1.24	.67	.76	2.70	.....	1.75	2.71	1.89	1.85	.....
	1911	1.09	2.32	1.06	.39	1.46	.72	1.07	.76	1.72	5.07	3.83	3.12	22.61
	1912	1.55	2.07	0	.11	.66	1.28	.93	1.06	2.52	4.71	1.02	3.79	19.70
	1913	1.67	.63	.63	1.01	.06	.76	1.35	1.83	3.89	4.05	2.88	4.22	22.98
Kodiak	1901	2.62	.30	3.85	.....	3.45	4.50	3.56	5.13	5.98	8.95	4.82	11.10	.....
	1902	3.89	6.29	4.33	3.26	5.55	1.55	1.87	6.15	.....	.....	.....	.....	.....
	1903	6.74	8.10	.39	4.61	4.92	7.80	4.38	4.79	7.95	6.27	3.40	8.29	67.64
	1904	3.63	.....	Tr.	2.68	3.35	2.26	1.36	4.89	4.63	5.54	5.20	3.24	.....
	1905	4.80	4.90	2.60	1.70	2.70	3.10	2.10	.....	1.80	.....	8.00	2.42	.....
	1906	2.50	8.60	3.50	3.80	5.10	.....	4.70	.....	1.50	6.70	5.10	3.20	.....
	1907	1.00	4.00	Tr.	.61	6.30	5.20	3.50	3.70	9.00	8.70	7.70	6.50	30.36
	1908	4.57	5.65	2.91	4.87	6.05	1.63	6.64	7.04	3.82	6.91	14.11	7.15	71.35
	1909	1.33	1.53	3.92	5.41	4.97	7.25	2.92	5.12	4.64	4.45	1.42	5.47	48.43
	1910	2.68	5.36	4.90	7.40	4.54	3.68	5.23	.....	3.62	8.18	5.38	6.73	.....
	1911	2.00	2.98	3.24	4.44	3.01	7.57	1.78	3.53	2.77	9.85	9.32	4.71	55.20
	1912	12.92	8.16	5.28	6.67	14.59	.....	.....	.....	.....	.....	.....	.....	.....
	1913	.....	.....	3.13	2.97	8.69	2.73	3.62	4.79	5.38	5.22	2.71	.....	.....
Loring	1904	.....	.....	2.05	7.27	15.80	9.68	7.97	1.15	20.20	26.01	31.90	20.01	.....
	1905	5.18	13.19	16.53	11.65	9.46	.84	5.26	12.71	14.07	17.94	28.49	25.92	161.24
	1906	21.66	6.08	8.56	24.52	5.59	10.09	4.99	15.21	17.28	20.49	21.57	8.41	164.45
	1907	.53	13.03	4.98	7.76	4.30	5.23	3.73	9.75	10.14	20.09	24.55	16.28	120.37
	1908	14.68	6.56	9.55	14.94	8.99	5.34	6.52	5.09	24.89	19.50	.....	9.30	.....
	1909	5.72	7.55	14.54	5.63	7.77	4.98	17.46	16.47	28.94	24.68	12.61	5.46	151.81
	1910	5.63	11.38	11.77	18.09	9.21	9.30	6.79	5.33	10.92	28.76	13.60	18.11	148.89
	1911	3.71	12.28	13.44	17.53	6.90	7.13	6.28	2.63	8.02	12.49	14.28	21.72	126.41
	1912	8.26	13.93	4.41	8.55	6.01	7.53	4.91	5.38	11.89	21.23	20.59	19.19	131.88
	1913	8.96	5.74	14.64	14.70	12.70	4.18	11.46	10.38	23.97	19.07	20.88	.....	.....
Seward	1908	.....	10.43	2.35	4.00	1.63	.45	3.35	6.34	4.29	9.73	20.99	12.38	.....
	1909	.52	.47	3.72	3.03	4.47	4.39	.72	3.71	3.66	8.92	.37	12.80	46.78
	1910	3.32	4.52	2.50	.55	1.43	2.59	2.15	2.45	7.12	5.72	1.55	4.31	38.21
	1911	1.45	5.67	2.30	4.12	2.66	2.95	1.89	2.55	3.28	9.30	4.96	1.29	42.42
	1912	.....	.....	5.77	4.29	8.33	.53	3.10	14.04	12.91	9.29	9.84	9.89	.....
	1913	2.76	3.52	3.37	6.24	2.68	.05	4.82	2.90	10.83	8.78	.....	.....	.....
Sitka	1901	9.33	6.38	7.80	7.17	4.86	1.26	.45	10.03	8.82	15.59	6.16	10.18	88.03
	1902	11.92	2.25	5.39	4.93	6.10	1.87	7.35	14.96	13.43	8.25	6.19	5.93	88.57
	1903	6.61	8.68	2.57	4.25	3.65	.90	2.85	3.90	5.80	14.52	6.50	14.97	75.20
	1904	10.36	.43	3.04	3.39	3.80	3.22	5.95	3.74	12.27	10.38	8.78	8.13	74.49
	1905	3.82	4.78	4.21	7.52	2.44	2.25	2.83	7.38	8.80	7.03	11.37	11.21	73.64
	1906	7.25	1.89	1.58	10.64	3.46	3.34	7.45	4.66	5.78	15.22	15.59	6.61	83.47
	1907	2.36	3.55	1.75	2.16	3.87	3.66	4.66	12.60	15.75	11.77	12.13	4.81	79.07

a July 7–31.

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Mean monthly precipitation at stations in southern Alaska since 1900—Continued.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Sitka	1908	7.54	6.57	4.74	9.58	3.82	1.39	3.45	7.52	15.85	10.65	7.20	.....	.....
	1909	1.49	2.43	12.97	4.67	4.47	3.29	5.14	6.62	16.98	10.46	3.83	5.45	77.80
	1910	10.06	5.17	6.51	6.13	3.44	3.47	3.74	3.35	8.04	7.34	3.87	11.48	72.60
	1911	9.39	8.37	8.65	5.98	3.21	2.76	2.84	2.30	5.96	10.98	8.36	.....	.....
	1912	3.18	5.90	5.01	2.67	3.66	3.49	3.84	9.07	8.27	15.13	9.92	19.87	80.01
	1913	.....	.....	.....	.....	3.98	.75	2.81	9.07	9.30	16.58	11.88	5.67	.....
Skagway	1901	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.92	.....	.....	.....
	1902	.....	.....	.....	.....	.13	.30	2.89	3.03	1.66	1.75	1.24	2.06	.....
	1903	2.08	1.44	.43	.48	1.10	.56	.02	2.06	1.41	9.99	1.60	3.35	24.54
	1904	1.44	Tr.	.33	2.31	.84	.97	1.07	.18	2.80	5.35	6.28	.....	.....
	1905	.....	1.14	1.14	1.27	1.11	.10	.16	2.14	2.67	2.17	3.25	2.21	.....
	1906	.....	1.16	.57	3.55	.37	2.63	2.11	2.26	1.30	5.58	6.47	.33	.....
	1907	.46	4.85	.47	1.08	.92	.39	.91	1.98	2.47	5.87	4.23	2.99	26.62
	1908	1.42	1.70	.23	.80	.70	.11	.48	.49	4.18	2.46	3.16	1.83	17.56
	1909	.....	.15	2.15	Tr.	.70	.68	2.43	.....	6.41	3.63	.....	.....	.....
	1910	2.80	1.40	4.80	1.38	.46	1.80	2.30	1.71	1.21	4.31	.....	.....	.....
	1911	.07	1.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1912	.15	2.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1913	.15	.75	.35	.65	.25	.30	.....	3.65	.....	.....	.....	.....	.....
Sunrise	1903	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.61	3.37	3.70	.....
	1904	1.69	.13	.28	5.08	1.01	1.36	1.05	5.02	2.33	9.35	2.37	8.31	37.96
	1905	2.12	1.93	1.64	3.41	.84	.69	1.40	4.46	1.86	4.36	9.47	8.48	40.66
	1906	2.18	.29	3.63	1.17	2.35	2.46	1.84	3.70	1.54	6.67	3.87	2.30	32.00
	1907	2.05	1.93	.....	1.41	1.30	.74	4.62	2.29	4.45	6.03	7.32	6.78	.....
	1908	7.03	4.68	2.00	3.37	2.63	.21	2.28	2.91	5.00	2.59	4.49	3.37	40.56
	1909	.54	1.05	2.71	.68	2.27	1.96	1.79	3.06	2.64	2.56	.40	3.36	23.02
	1910	3.22	4.39	1.66	1.55	.86	1.44	1.79	1.74	2.80	4.34	2.29	4.06	30.14
	1911	1.20	6.01	2.44	4.74	1.34	.89	1.61	1.40	3.59	5.20	3.64	3.25	35.31
	1912	3.41	5.24	1.20	2.86	6.12	.63	.....	3.13	5.44	5.90	8.80	5.40	.....
	1913	.96	1.37	.45	3.17	.78	.07	1.64	2.04	3.70	4.35	4.67	.....	.....
Tiekel	1904	.....	.....	.05	.75	.40	.79	1.53	2.00	1.21	2.82	.90	2.95	.....
	1905	.98	.49	1.31	.04	Tr.	.80	1.05	1.02	1.41	1.48	4.90	2.34	15.82
	1906	2.50	.20	1.87	.58	.25	1.39	2.70	.72	.62	2.90	3.52	.36	17.61
	1907	.37	1.81	.56	.07	.80	.68	8.20	2.00	1.20	.....	.....	.....	.....
Tyonek	1901	1.55	.05	.62	1.00	.04	.53	2.68	5.77	3.16	4.42	.45	1.13	21.55
	1902	3.08	.52	1.09	.71	.38	0	2.93	5.40	6.56	4.96	.94	1.72	28.29
	1903	1.95	3.91	.45	1.01	.69	1.59	2.62	5.69	2.76	1.15	.64	.53	22.99
	1904	1.07	.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1905	.....	.....	.....	.....	.....	1.27	.92	4.75	.92	3.19	3.10	1.24	.....
	1906	.65	.49	1.32	.77	.39	1.00	2.96	2.95	1.67	.....	1.04	1.38	.....
	1907	1.96	1.08	1.66	.24	.....	2.86	6.39	3.05	5.76	3.48	2.18	.57	.....
	1908	1.98	.99	.....	.....	.39	.25	.....	.....	.....	1.30	1.21	1.86	.....
	1909	.58	.53	.99	2.38	.....	.....	.....	.....	.....	.....	.....	.....	.....
Valdez	1909	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.81	.32	14.90	.....
	1910	6.78	3.08	3.47	.79	4.43	2.68	2.60	2.94	8.09	8.73	1.47	3.00	48.06
	1911	2.82	7.43	6.08	4.52	2.72	2.46	2.81	1.07	2.52	3.75	3.00	9.27	48.34
	1912	3.04	4.97	10.97	.71	5.45	1.23	5.10	7.05	18.74	6.99	2.47	9.14	75.86
	1913	4.00	8.63	1.43	2.82	1.78	.64	4.38	6.20	6.95	4.66	6.20	8.63	56.32

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Daily precipitation, in inches, at various stations in south-central Alaska for 1913.

Copper Center.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.[a]	Annual.
1											1.08		
2													
3													
4													
5							0.22				.22		
6													
7													
8													
9													
10		0.13											
11							.27						
12						0.33		0.35					
13					0.09						.35		
14													
15													
16													
17													
18										0.25	.70		
19													
20													
21													
22							.19						
23									0.80				
24						.20			.37				
25													
26	0.83						.22						
27		.14			.06		.32		.09				
28							.08	.35					
29						.36		.29					
30													
31													

[a] Total for December 0.55 inch.

Cordova.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1	0.68	0.53		0.65				0.16		1.45	3.45	0.85	
2							0.15	.01	1.15		2.80	.17	
3							.02		.10	.14	.63	.46	
4			0.39	.10			Tr.	.01	.03	.80		.43	
5				.16				.18		.17		.70	
6						0.02		.26				.78	
7			.10				.08	.06				.27	
8			1.35				.01	1.08				1.10	
9			.56			.38	Tr.	2.02				.18	
10	.20	.12	.65	.20		.12			.10			.16	
11		.23	.01						.12		.85	.59	
12		.30			0.12				2.07		4.23	.25	
13			.05	.67	.48				.57	.11	.31	2.05	
14			.02						1.78		.78	1.46	
15		.49		.40			.20		1.71		.11	.05	
16		.65		.65			.33	.01	.09				
17		.43		.42	.22	.03	.73		.01		.18		
18		3.88		.22	.48		1.55		.16	.60	1.03	.25	
19		.30		.50	.53		2.15		.53	2.26		.66	
20		.12		.96			2.03	.02	.12	.08	.02	.04	
21				.20				.05		.74	.63	.09	
22	.12				.48		.75		1.91	2.38	.60		
23	.04			.37	.43	Tr.	.54		2.03	.74	.40	.53	
24	.05		.25	.48	.08	.12		.35	2.22	.74	.06	.51	
25	.28		.15			.07	.07		.78	.36		.27	
26	.60						.38	.91	.13		.05		
27			.30				.07	2.40	.12			.34	
28	.08	.53	.05				1.00	.90	.37		.15	1.38	
29				.98		.28	.83	.04	.56	1.30	.23	.85	
30				.76		.76	1.63		2.42	2.20	.68	1.46	
31	.72		.10				.25			1.02		.14	

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Daily precipitation, in inches, at various stations in south-central Alaska for 1913—Continued.

Juneau.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1	0.20	0.28	0.15	0.11	0.08		0.25			1.00	0.10		
2	.19	.11	.02	.14	.22		.24	0.04		.03	.16		
3	.04		.25	.03	.25			Tr.	0.02		.46		
4	.07		.20	.31	.02		.01	.53	.16	.03			
5	.31		.37			0.18	.17	.40	.13	.46	.01		
6	.90		.60	.04				1.30	.03	.04	.03		
7	.15			.03			.07	.31	.72	.25	.35		
8		.14	.18			.11	1.08	.08	.06	.40	.46		
9			.21	.14		.02		.40	.40	.20	1.10		
10	.21		.10	.15			.06		.11	.01	.52		
11		.48				.08	.80		.90	.05	.06		
12		.30		.08	.15	.10			.61	.16	.13		
13		.50		.38	.27	.10			.44	.40	.31		
14		.57	.12	.15				.02	.92	.16	.66		
15		.45	.20	.05			.22		.78	.40	.70		
16		.25		.34	.01		.10		.46	.73	.02		
17		.12		.08			.22		.09	.55			
18	Tr.	.48		.42			.63			.82	.80		
19	.11	.10		.03	.71		.15		.65	3.50			
20	.36	Tr.		.05	.07				.77	.97			
21	.11	.22		.03	.11				1.45	.90	.25		
22	.43			.21	.30	.03			.65	.76	.25		
23	.58			.19	.18			.05	.35	.60	.12		
24	.09				.04			.67		1.15	.01		
25	.19	Tr.	.50	.02	.25			.90		1.10			
26	.24		.57	.04	.66		.42	.34	.01	.15			
27	.25	Tr.	.13	.07	.12		.72	1.80	.03		.36		
28	.30	.43	.12		.36	.10		1.55	.90		.38		
29	.04				.63		.68	Tr.	1.30	.10	.01		
30	.40		.25	.58	.43		.37	Tr.	.20		.51		
31	.04		.23		.53		.31			.22			

Seward.

1		0.70	0.13	0.25	0.15					0.37			
2		.20	.18				Tr.						
3										.77			
4	0.35		.30							.83			
5	.20		.60						0.05	.07			
6				.02					.12				
7			.09										
8			.97					1.00					
9	.25		.03	.12		0.02		.20					
10		.10	.10			Tr.							
11					Tr.								
12		.10		.55			Tr.						
13				.10					.18				
14		.12		.48			Tr.						
15		.25		.48			0.10		Tr.				
16		.30		1.10			.11	Tr.					
17		.42		.33	1.00		.12						
18					.18		.45		.20	Tr.			
19	.05	1.00		.63	Tr.		.81	.08	1.22	1.48			
20		.20		.18	.03		.91	.10	Tr.				
21				.30				.04		.14			
22				.28	.30		.44	.05	.86	1.05			
23				.22	.22	.03			1.98	.14			
24			.20	.20	Tr.			.02	2.40				
25	.17		.53				.27		2.45	.18			
26	.10		.05				.27	.54	.10				
27	.37	.13						.87	.05				
28			.12	.15			.46		Tr.	.24			
29				.62	.15		.68		.15	.38			
30	.47			.23	.05		.20		1.07	2.58			
31	.80		.07		.60		Tr.			.55			

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Daily precipitation, in inches, at various stations in south-central Alaska for 1913—Continued.

Sunrise.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1	0.02	0.49	Tr.	0.28	0.08	.....	.....	.....	.....	0.38	1.49	.....	.....
2	.01	.25	Tr.	.....	.02	.....	.....	.....	.....	.19	2.13	.....	.....
3	.13	.02	.....	.....	Tr.	.....	.....	.....	.....	Tr.	Tr.	.....	.....
4	.07	.....	0.12	.03	.....	.....	.....	Tr.	.....	.33	Tr.	.....	.....
5	.01	.....	.15	.09	Tr.	.....	.....	Tr.	0.01	.29	.....	.....	.....
6	Tr.	.....	.01	.....	Tr.	.....	.....	0.01	Tr.	.02	.06	.....	.....
7	.....	.....	.03	.....	.....	.....	.....	Tr.	.....	.10	Tr.	.....	.....
8	.....	.....	Tr.	.....	.....	.....	Tr.	.10	.....	.06	.....	.....	.....
9	.18	.....	.02	.06	.....	.....	0.06	.06	.....	.02	.....	.....	.....
10	Tr.	.....	.04	.....	.....	.....	.....	.39	.....	.....	Tr.	.....	.....
11	.04	.....	.....	.....	Tr.	.....	.....	.....	.....	.....	.11	.....	.....
12	Tr.	.....	.....	.02	Tr.	.....	Tr.	.....	.....	.....	.14	.....	.....
13	.01	Tr.	Tr.	.11	.....	.....	.....	.....	.04	.....	.09	.....	.....
14	.....	Tr.	.....	.01	.....	.....	.....	.....	.01	.....	Tr.	.....	.....
15	.....	.02	.....	.26	.....	.....	.21	.....	.06	.....	.....	.....	.....
16	.....	.01	.....	.04	.....	.....	.25	.13	.03	.....	.....	.....	.....
17	.....	.01	.....	.05	.22	.....	.02	.....	.08	.....	.14	.....	.....
18	.....	.16	.....	.....	.08	.....	.04	Tr.	.07	.32	.09	.....	.....
19	.17	.01	.....	.98	.....	.....	.06	.07	.03	.38	.....	.....	.....
20	Tr.	.09	.....	.41	.04	.....	.24	.03	.....	Tr.	.02	.....	.....
21	Tr.	.....	.....	.52	.01	.....	Tr.	.01	.....	.12	.37	.....	.....
22	.....	.....	.....	.03	.09	.....	.17	.....	.26	.31	Tr.	.....	.....
23	.....	.....	.....	.09	.....	0.04	.02	.....	.24	.30	.01	.....	.....
24	.06	.....	.01	.03	.....	.....	.....	Tr.	.99	.08	.01	.....	.....
25	.02	.....	Tr.	.....	.....	.....	.13	.01	1.46	.09	.....	.....	.....
26	.18	.....	.02	.....	.....	.....	.10	.15	Tr.	.....	.....	.....	.....
27	.01	.02	.03	.....	Tr.	.....	.01	1.03	.02	.....	.....	.....	.....
28	.01	.29	.01	Tr.	.13	.....	.27	.05	.23	Tr.	.01	.....	.....
29	.02	.....	.....	.07	.04	.03	.01	.....	.05	.07	.....	.....	.....
30	Tr.	.....	.....	.09	.05	.....	.05	.....	.12	1.25	.....	.....	.....
31	.03	.....	.01	.....	.02	.....	.....	.....	.....	.09	.....	.....	.....

Valdez.

1	.....	1.39	Tr.	0.02	0.13	.....	.....	Tr.	.....	0.18	1.45	0.26	.....
2	Tr.	.13	.....	.....	.14	.....	0.07	.....	0.04	.05	.33	1.01	.....
3	0.04	Tr.	.....	.....	.....	.....	.03	.....	.....	.06	.38	.39	.....
4	.09	.....	0.11	.....	.....	.....	.01	0.01	.....	.50	.04	.29	.....
5	.60	.....	.24	.....	.....	.....	.....	.01	.....	.52	.....	.39	.....
6	.06	.....	.....	.....	.....	.....	.02	.46	.....	.01	.....	.20	.....
7	.....	.....	.13	Tr.	.....	.....	.02	.02	.....	.03	.....	.23	.....
8	.....	.....	.54	.02	.....	.....	.06	.56	.....	.....	.....	.81	.....
9	Tr.	.....	.13	.....	.....	0.22	.....	.45	.....	.....	.....	.03	.....
10	.....	.....	.....	.....	.....	.09	.01	.02	.09	.....	.....	.02	.....
11	.04	.14	Tr.	.....	.....	.....	.10	Tr.	.01	.....	.....	.02	.....
12	Tr.	.12	.....	.03	.31	.....	.....	.01	.24	.....	1.22	.....	.....
13	.....	.....	Tr.	.24	.37	.....	.....	.01	.43	Tr.	.33	1.32	.....
14	.....	.....	.....	.02	.....	.....	.....	.....	.41	.....	.10	.17	.....
15	.....	1.17	.....	Tr.	.....	.....	.16	.....	.34	.....	.....	.11	.....
16	.....	.43	.....	.....	Tr.	.....	.02	.02	.01	.....	.....	.....	.....
17	.....	1.14	.....	.....	.06	.....	.15	.....	.02	.....	.31	.....	.....
18	.....	1.47	.....	.22	.12	.....	.35	.....	Tr.	.15	1.13	.04	.....
19	.03	.54	.....	.12	.39	.....	.35	Tr.	.15	.61	.....	Tr.	.....
20	Tr.	.42	.....	.90	.....	.....	.75	.10	.....	.20	.03	.....	.....
21	.....	.08	.....	.07	.02	.....	.01	.07	.....	.13	.21	.....	.....
22	.....	.....	.....	.16	.07	.....	.35	Tr.	1.13	.60	.31	.07	.....
23	.08	.....	.....	.17	.08	.02	.12	.....	2.00	.06	.22	.28	.....
24	.10	.04	.....	.04	.....	.....	Tr.	.03	1.12	.10	.04	.08	.....
25	.89	.....	.27	Tr.	.....	.29	.16	.05	.39	.21	.....	.....	.....
26	.22	.....	Tr.	.....	.....	Tr.	.56	.45	.11	.....	.....	.....	.....
27	.61	.23	Tr.	.....	.....	Tr.	.06	2.95	.01	.....	.....	.08	.....
28	.25	1.33	.....	.03	.....	.....	.44	.65	.11	.....	.06	.50	.....
29	.46	.....	.....	.33	.04	.02	.41	.07	.14	.29	.01	.85	.....
30	.39	.....	.....	.45	.03	.....	.12	.26	.20	.78	.03	.88	.....
31	.14	.....	.01	.....	.02	.....	.05	Tr.	.....	.18	.....	Tr.	.....

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The records vary widely and indicate some very pronounced characteristics of areal distribution. The greatest annual precipitation in the Territory apparently occurs in the southern part of the Alexander Archipelago, at Loring, Ketchikan, and Metlakatla, the average being 144 inches. To the north there is an evident decrease, for at Calder and Sitka the records are 106 inches and 84 inches, respectively. At Killisnoo and Juneau, which are somewhat protected from oceanic influences, the records are 51 and 76 inches. At Skagway and Klukwan, which lie considerably inland from the open ocean, the average precipitation is 23 inches.

To the west the first point at which observations have been made is Katalla. The records there and at Nuchek and Cordova indicate another region of remarkably heavy precipitation. The maximum is recorded at Nuchek, but the record was so short that probably less reliance should be placed on it than on the longer records at Katalla and Cordova, of which the average is 132 inches.

Fort Liscum and Valdez are at the upper end of Port Valdez and somewhat protected from the ocean might be expected to receive less rainfall than places more exposed. At Fort Liscum the record is 74 inches, whereas across the bay it is 58 inches, a rather marked variation for so short a distance—4 miles. The fact that Fort Liscum is situated at the base of a steep mountain slope and Valdez on a broad, low delta, 1½ miles from the foot of the nearest mountain, account for the phenomenon. (See p. 89.)

Marked differences in the precipitation at the different stations are found also on Kenai Peninsula. From Seward, where the recorded precipitation is 59 inches, the amount decreases to 34 inches at Sunrise on the north, and to 17 inches at Kenai. Conditions similar to those at Kenai apparently prevail at Tyonek, which is situated a few miles north of Kenai and across Cook Inlet, the mean annual precipitation at that point being 23 inches.

The annual precipitation at Kodiak—62 inches—is not very different from that at Seward. On the eastern shore of the Alaska Peninsula there is a record of 49 inches at Coal Harbor, but on the western coast a smaller precipitation is indicated by the records of 24 and 31 inches at Ugashik and Nushagak, respectively.

Farther west the precipitation apparently increases, for at Dutch Harbor the mean is 79 inches, and still farther west, at Atka Island, it is 89 inches. The most western station at which records have been obtained is Bering Island, where the mean is 21 inches.

North of the Chugach Mountains there is a very marked decrease in rainfall. Tiekel, situated in the northern foothills of these mountains, has a record of 18 inches. At Chickaloon, Copper Center, and Chistochina conditions of precipitation appear approximately the same, the average being 10 inches per year and indicating a region of low precipitation including a large part of the Chitina, upper Copper,

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and Matanuska valleys. This does not mean, however, that the precipitation on the mountains in this region may not be much higher than that at the station affording the data.

Neither the object of this paper nor the information at hand justifies a very comprehensive discussion of the meteorology of the region, but it seems advisable to call attention to certain influences that produce the wide variation of precipitation in Alaska noted in the foregoing paragraphs.

The cooling of air to the point at which the moisture it carries is precipitated as rain or snow may be caused by various conditions, but the cause most active along the Alaska coast is the passage of the relatively warm southerly winds, laden nearly to the point of saturation with moisture that has been collected by evaporation from the Pacific Ocean, over the cool land areas.

The exposure of the locality to the ocean winds and its position with respect to surrounding topographic features probably explain many of the variations in precipitation found in the coastal province. At the foot of a high, steep mountain side exposed to the moisture-laden winds the rainfall will be heavier than at a place similarly situated on the leeward side, and it will also be greater than at a place exposed to the same winds but lacking the mountain background, since the cool mountain air is very effective in precipitating the moisture. Thus an area that is protected from the prevailing winds by mountains, islands, or projections of mainland would receive less precipitation than an area not so protected.

The great mountain systems lying across the course of the prevailing winds also serve as effective obstructions to the passage of moisture to the interior. The moisture-laden southwesterly air currents passing up the mountain sides become increasingly cooler and continue to deposit their excess moisture, and at the summit their moisture content represents the capacity of the air at that temperature. As they descend on the other side they usually enter a warmer region, and there tend to retain their moisture until they are cooled below the temperature prevailing at the mountain summit over which they have passed.

This phenomenon explains some of the peculiarities of the distribution through the year. The diagram, figure 2, shows clearly that along the coast, owing to the lowering of the land temperature and to other physical causes, precipitation is heaviest during September, October, November, and December.

Across the Chugach Mountains the annual rainfall is greatly reduced and the period of heaviest rainfall apparently begins in midsummer. In the interior[1] rainfall is heaviest in June, July, and August, the warmest season of the year, the reason being that the higher tem-

[1] Ellsworth, C. E., and Davenport, R. W., U. S. Geol. Survey Water-Supply Paper 342, p. 41, 1915.

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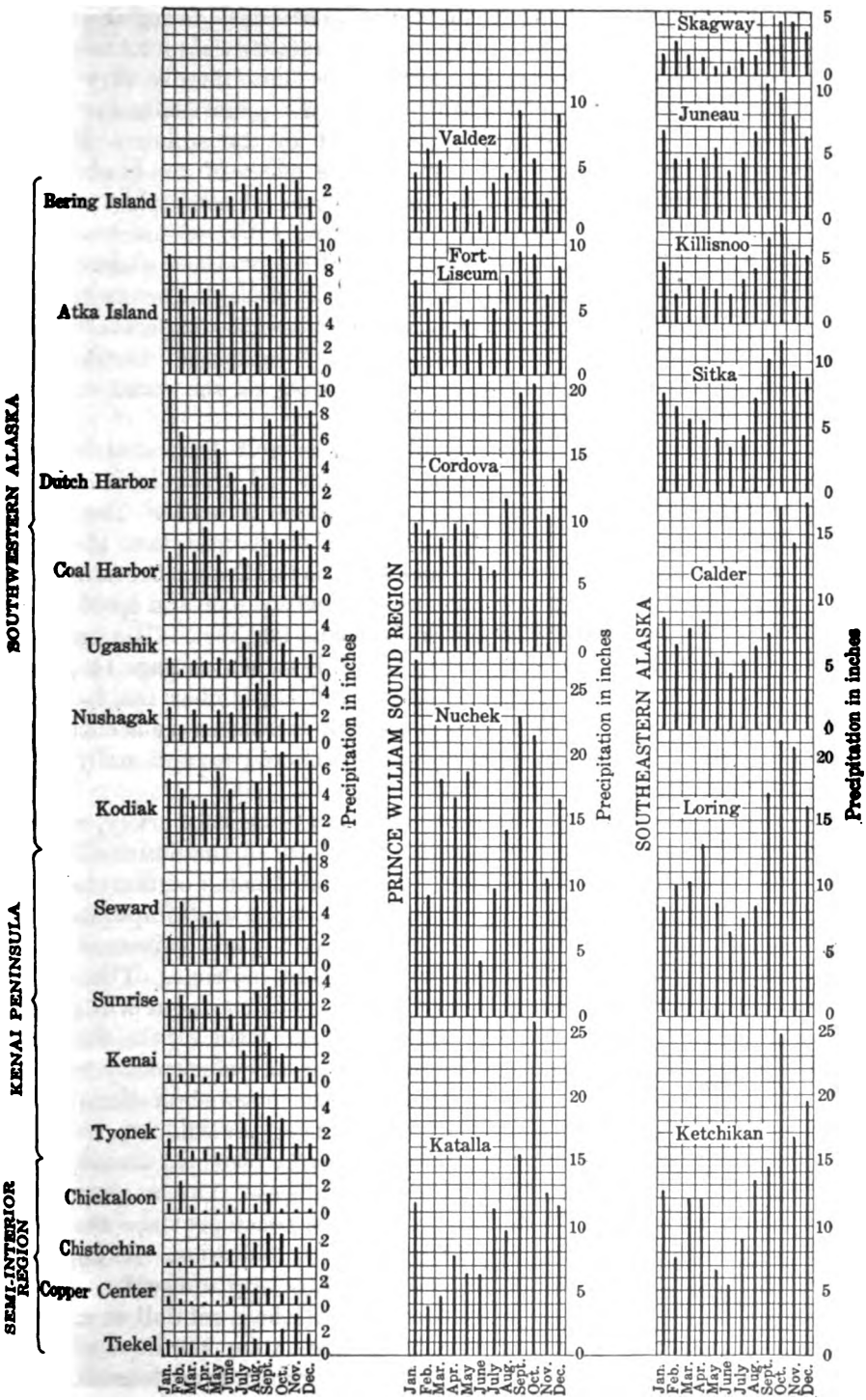

FIGURE 2.—Diagram showing monthly distribution of precipitation in southern Alaska.

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peratures on the coast and at the mountain summits during the summer allow the passing winds to carry more moisture into the interior.

The effect of altitude on precipitation is undoubtedly very pronounced in this region. The evidences do not seem conclusive that the increase is continuous from the coast to the summits of the mountains, for the maximum precipitative effect of the land temperature acting on the warm sea air might be at some place below the summit. After the air has been unburdened of much of its moisture at the first mountain summits and has attained a more uniform humidity, the tendency is toward increase in precipitation where the lower temperatures prevail. Decrease in temperature and therefore increase in precipitation usually accompanies increase in elevation. This fact has an important bearing on the water supply of some of the inland area.

The effect of elevation on precipitation is well illustrated in the Cook Inlet country. At Kenai the mean annual precipitation is 17 inches, at Tyonek 23 inches, and at Chickaloon 9 inches. The last-named station lies within the region of low precipitation already noted. About 30 miles west of Chickaloon is the Craigie Creek drainage area, most of which lies at elevations between 2,000 and 4,000 feet, whereas the altitude of Chickaloon is about 900 feet. The run-off from Craigie Creek at the Gold Bullion mill is shown on page 145, and for the months of June, July, August, and September the total is 32.52 inches. The size of the drainage area has been very accurately determined. The season of 1913 was considered exceptionally dry throughout the Cook Inlet country.

A topographic party of the United States Geological Survey, working throughout the summer of 1913 at the head of the Susitna River on the south slope of the Alaska Range, noted some of the characteristics of precipitation in that area. The season was comparatively dry to July 10, but thereafter until September 1 it was estimated that rain and fog prevailed more than two-thirds of the time. The same period in the lower Susitna Valley and Cook Inlet region was practically rainless. Moreover the natives at the head of the Susitna were reported as saying that the season was not abnormally rainy. These comparisons indicate a large increase of precipitation with increase in altitude in the interior region during the summer.

The maximum rainfall in 24 hours very rarely reaches 7 inches, but frequently exceeds 3 inches at the wettest places. The maximum is somewhat greater in the eastern part of the coast province than in the western, and it decreases rapidly toward the interior. At Copper Center a 24-hour rainfall in excess of 1 inch is very unusual.

At some of the stations in southeastern Alaska a rainfall in excess of one-hundredth of an inch occurs on more than 200 days of the year. In the western part the number of rainy days decreases to

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about 150. At the more inland areas, such as on Upper Lynn Canal and the Cook Inlet region, the number of rainy days does not much exceed 90 per year. The average number of rainy days per year at Copper Center is 63. Thus the maximum rainfall in a 24-hour period and the number of rainy days in a year are seen to bear a well-defined relation to the quantity of annual rainfall.

A study of the water supply of a region obviously involves the question of snowfall. The principal factors determining the amount of snowfall are the quantity of precipitation and the temperature at which such precipitation occurs. In southeastern Alaska, because of the relatively high winter temperature, there is little snow at sea level, but at higher elevations it is very heavy. At White Pass the winter snowfall is about 25 to 30 feet, but on the Chilkat summit it is said to be less than 4 feet. Farther west, owing to the lower winter temperature, the snowfall is heavier. The total at Seward is reported as about 6 feet, at Valdez 12 feet, and at Cordova about 10 feet. At Thompson's Pass 15 feet is reported. These figures are approximate and vary considerably from year to year.

On May 6, 1913, 5 feet of snow was measured on the extensive flat area back of the town of Valdez. A few days later, on May 16, the depth on this flat had decreased to 2.5 feet, with a water equivalent of 26 per cent.

On May 9, 1913, a trench was observed which had been dug through the snow for a considerable distance alongside of Solomon Gulch for the purpose of installing a pipe line for a hydroelectric development. The locality is on the south side of Port Valdez, 500 or 600 feet above sea level. The snow at that time varied in depth from 6 to 18 feet and probably had been considerably greater earlier in the spring.

The snowfall higher in the mountains is undoubtedly enormous, as is indicated by the early date at which the snow line commenced to descend the mountain side, and the fact that perennial snow and glaciers are not uncommon. This heavy snowfall is of considerable practical significance in its effect on run-off, and also because of its tendency to produce great snowslides in the winter and especially in the spring when the masses of snow commence to thaw on the precipitous mountain slopes. Owing to their wide prevalence they threaten the stability of any structure lying in their path and present a serious obstacle to mining, railroad, or water-power development.

In the Kenai Valley at the elevation of Kenai Lake the annual snowfall is about 6 feet. On December 16, 1913, a depth of 4 feet was reported in this region as being an exceptionally heavy fall for that season. Farther north, in the regions of lower precipitation, the snowfall is less. The transition from coast to interior conditions is well illustrated along the Copper River. On the Copper River Flats

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there is a fall of 15 to 30 feet. The Copper River & Northwestern Railway has found the difficulty of keeping the track clear of snow by their rotary plows much greater below the mouth of Tiekel River at mile 101 than above. At Chitina there are 3 to 4 feet of snow, about 4 feet are reported at Kennicott, and 3 feet at Copper Center. On May 22, 1913, there was about 5 feet of snow at the delta of the Copper, with a gradual decrease northward until at Chitina, 100 miles to the north, the ground was bare up to an elevation of over 2,000 feet.

The average depth of accumulated snow near Miles Glacier during 1907 and 1909 is shown in the following table. The observations were kept by the Copper River & Northwestern Railway during the construction of the road:

Average depth of snow, in feet, near Miles Glacier for 1907–1909.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1907.											
1	.....	0.6	3.2	11	.....	2.0	3.6	21	.9	2.0	3.9
2	.....	.6	3.1	12	0.0	2.0	3.8	22	.8	2.5	4.0
3	.....	.6	3.1	13	.8	1.9	4.0	23	.7	2.5	4.0
4	.....	.7	3.0	14	1.1	1.9	4.0	24	.6	2.5	4.0
5	.....	1.0	3.0	15	1.3	1.9	4.0	25	.5	2.5	4.0
6	.....	1.5	3.0	16	1.5	1.9	4.0	26	.5	2.6	4.0
7	.....	1.8	3.0	17	1.3	1.9	3.9	27	.4	3.0	4.0
8	.....	2.0	3.1	18	1.2	1.9	3.9	28	.3	3.2	4.0
9	.....	2.0	3.3	19	1.1	1.9	3.9	29	.3	3.2	4.0
10	.....	2.0	3.5	20	1.0	1.9	3.9	30	.5	3.2	4.0
								31	.6	.....	4.2

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Oct.	Nov.	Dec.
1908.									
1	4.5	8.0	9.6	9.1	9.8	2.6	.....	0.1	0.4
2	4.8	8.0	9.5	9.2	9.7	2.5	.....	.1	.4
3	5.2	8.0	9.5	9.3	9.6	2.3	.....	.2	.3
4	5.6	8.0	9.4	9.4	9.5	2.0	.....	1.0	.2
5	5.9	8.0	9.4	9.5	9.4	1.7	.....	1.5	.1
6	6.4	7.9	9.3	9.5	9.3	1.5	.....	1.6	.1
7	6.6	7.9	9.3	9.6	9.2	1.4	.....	1.7	.1
8	6.7	7.9	9.3	9.7	9.0	1.2	.....	1.0	.2
9	6.9	8.0	9.3	9.8	8.7	1.0	.....	.2	.8
10	7.0	8.1	9.2	9.9	8.5	.8	.....	0.0	.4
11	7.1	8.0	9.1	10.1	8.3	.6	.....	0	.8
12	7.1	8.0	9.1	10.3	8.1	.5	.....	0	.8
13	7.0	8.2	9.1	10.5	7.7	.3	.....	.2	.8
14	7.0	8.5	9.0	10.7	7.5	.2	.....	Trace.	.9
15	7.0	9.0	9.0	10.9	7.3	0.0	.....	Trace.	.8
16	7.0	9.4	9.0	11.1	7.0	.....	.....	Trace.	.8
17	7.0	10.0	9.0	11.3	6.7	.....	.....	Trace.	.7
18	7.1	10.0	9.0	11.4	6.5	.....	0.0	Trace.	.6
19	7.1	10.0	9.0	11.5	6.2	.....	.2	Trace.	.8
20	7.2	9.9	8.9	11.4	6.0	.....	.2	Trace.	1.2
21	7.2	9.9	8.9	11.3	5.7	.....	.2	Trace.	1.6
22	7.2	9.8	8.9	11.1	5.4	.....	.3	Trace.	1.6
23	7.2	9.8	8.9	11.0	5.0	.....	.7	Trace.	2.8
24	7.3	9.8	9.0	10.8	4.7	.....	.7	Trace.	3.6
25	7.5	9.7	9.0	10.6	4.5	.....	.1	Trace.	3.9
26	7.6	9.7	9.0	10.3	4.2	.....	.1	.1	4.0
27	7.7	9.7	9.0	10.2	3.8	.....	.2	.4	4.0
28	7.8	9.6	9.0	10.0	3.6	.....	.1	.4	4.0
29	7.9	9.6	9.0	9.9	3.3	.....	.1	.3	4.0
30	8.0	.....	9.0	9.8	3.0	.....	.1	.4	4.0
31	8.0	.....	9.1	.....	2.8	.....	.1	.....	4.0

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Average depth of snow, in feet, near Miles Glacier for 1907–1909—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Oct.	Nov.	Dec.
1909.								
1	4.0	6.5	6.9	6.7	3.9	0.1	0.2	0.2
2	3.8	6.5	6.9	6.6	3.8	.3	.3	.3
3	3.7	6.5	6.9	6.5	3.7	.5	.4	.6
4	3.6	6.5	6.9	6.5	3.6	.6	.5	.9
5	3.4	6.5	7.0	6.4	3.5	.7	.6	1.1
6	3.2	6.5	7.0	6 3	3.4	.7	.6	1.2
7	3.0	6.5	7.0	6.2	3.3	.7	.6	1.1
8	2.8	6.6	7.0	6.1	3.2	.7	.6	1.1
9	2.7	6.6	7.0	6.0	3.1	.6	.5	1.1
10	2.5	6.7	7.0	5.9	3.0	.5	.5	1.4
11	2.4	6.7	7.0	5.8	2.9	.3	.5	2.0
12	2.2	6.7	7.0	5.7	2.7	.2	.4	2.1
13	2.1	6.7	7.0	5.6	2.6	.1	.4	2.0
14	2.0	6.7	7.0	5.5	2.5	0	.4	1.6
15	1.8	6.7	7.0	5.4	2.3	0	.4	1.5
16	2.0	6.8	6.9	5.4	2.2	0	.3	1.4
17	2.2	6.8	6.9	5.3	2.1	0	.3	1.3
18	2.6	6.8	6.9	5.2	1.9	0	.3	1.2
19	3.0	6.7	6.9	5.1	1.8	0	.3	1.1
20	3.2	6.7	6.9	5.0	1.7	0	.3	1.0
21	3.4	6.7	7.0	4.9	1.5	0	.3	1.1
22	3.6	6.7	7.0	4.8	1.3	0	.3	1.2
23	3.8	6.7	7.0	4.7	1.2	0	.3	1.2
24	4.0	6.8	7.0	4.6	1.0	0	.3	1.2
25	4.5	6.8	7.0	4.5	.9	0	.2	1.2
26	4.7	6.9	6.9	4.4	.7	0	.2	1.2
27	5.0	6.9	6.9	4.3	.6	0	.2	2.0
28	5.3	6.9	6.9	4.2	.5	0	.2	2.0
29	5.8	.....	6.9	4.1	.3	0	.2	1.9
30	6.3	.....	6.8	4.0	.2	0	.2	1.5
31	6.5	.....	6.8	.....	0	0	.....	1.2

NOTE.—Records furnished by the Copper River & Northwestern Railway.

Maximum velocity of wind, in miles per hour, near Miles Glacier for 1908–9.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908.							
	.....	12	4	6	20	60	20
	3	12	9	20	24	50	24
	10	8	12	10	15	52	20
	15	7	22	9	5	48	23
	8	20	18	12	10	60	15
	4	12	4	20	12	30	20
	8	11	8	20	20	24	.....
	7	10	8	8	.....	24	.....
	8	20	8	30	20	24	12
	12	15	11	5	20	20	18
	10	6	7	7	12	12	20
	12	16	9	20	32	12	40
	10	14	5	13	20	12	40
	4	13	8	4	25	19	38
	9	9	13	20	30	20	50
	8	5	11	24	24	22	25
	6	8	6	40	30	36	24
	12	12	13	10	20	24	20
	18	18	24	10	42	37	20
	9	8	7	45	48	32	15
	6	11	30	24	70	36	24
	.....	16	11	20	70	40	30
	12	4	13	20	48	34	20
	12	10	8	36	42	12	20
	14	8	12	30	40	8	20
	.....	12	8	24	48	24	25
	7	10	11	24	64	12	50
	11	5	6	20	48	20	65
	14	6	8	0	60	12	70
	8	8	12	40	38	12	48
	.....	9	12	.....	31	.....	30

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Maximum velocity of wind, in miles per hour, near Miles Glacier for 1908-9—Contd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909.												
1	60	72	37	0	12	25	9	(a)	10	12	20	25
2	60	50	50	24	0	20	12	.....	8	34	22	30
3	50	50	50	20	12	22	8	.....	18	21	31	43
4	36	55	37	8	20	8	10	.....	15	45	8	80
5	50	60	30	26	8	8	9	.....	12	40	25	75
6	55	65	25	36	8	17	12	.....	18	30	29	68
7	60	50	30	37	10	15	20	.....	15	34	43	62
8	72	55	30	20	0	15	11	.....	7	47	38	49
9	72	60	60	0	10	18	12	.....	7	32	38	45
10	64	60	36	0	12	15	13	.....	12	20	33	15
11	60	40	50	30	20	16	8	.....	12	12	12	5
12	40	50	48	12	20	17	20	.....	20	30	16	27
13	50	70	22	31	10	8	14	.....	35	10	4	40
14	51	84	24	48	8	9	12	.....	15	12	4	37
15	60	72	.....	48	0	15	13	.....	31	28	45	37
16	65	66	12	24	4	16	12	.....	12	30	65	32
17	70	36	0	10	8	15	15	.....	12	42	60	27
18	70	12	20	17	10	20	8	.....	10	60	55	27
19	70	36	24	0	0	10	12	.....	14	48	54	16
20	71	50	23	20	12	8	7	.....	24	58	47	37
21	70	40	35	10	20	12	12	.....	35	50	60	20
22	70	60	18	24	8	14	20	.....	36	22	60	20
23	50	65	50	49	8	8	12	.....	38	25	60	21
24	65	34	36	12	20	18	15	.....	31	8	67	27
25	30	24	24	20	15	20	13	.....	32	5	63	20
26	50	36	36	10	27	15	6	.....	30	15	67	28
27	60	20	17	10	8	24	5	.....	30	30	67	30
28	65	24	40	40	12	20	10	.....	24	30	68	38
29	54	.....	12	0	20	12	15	.....	15	25	65	30
30	70	.....	15	6	20	10	14	.....	15	17	47	66
31	72	.....	0	.....	20	.....	8	.....	.....	20	.....	66

a No records during August.

NOTE.—Records furnished by the Copper River & Northwestern Railway.

TEMPERATURE.

Perhaps no meteorologic phenomenon in southern Alaska has a greater influence on the regimen of streams than temperature, for most of the streams head in glaciers or perennial snows, and on such streams the effect of temperature equals or exceeds that of rainfall. In the interior regions, where the temperature seldom goes above the freezing point for several months each winter, the run-off becomes entirely dependent on underground sources, whereas on the coast occasional periods of thawing weather augment the flow to an important extent.

The temperature conditions at various representative stations in southern Alaska are summarized in the following table:

Summary of temperature records at various Weather Bureau stations in southern Alaska.

Copper Center.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	49	49	49	64	80	96	87	87	80	66	49	50	.....
Minimum	−74	−55	−48	−26	18	22	22	20	3	−26	−46	−53	.....
Mean	−10.8	2.3	14.3	29.0	44.1	53.1	55.4	52.4	42.9	27.7	4.6	3.3	27.1

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Summary of temperature records at various Weather Bureau stations in southern Alaska—Continued.

Cordova.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	47	58	61	70	72	80	86	80	84	72	60	49	.....
Minimum	2	4	1	15	28	34	33	40	31	26	11	5	.....
Mean	27.8	30.3	31.6	37.0	44.8	50.9	56.2	55.4	48.7	43.9	33.2	29.7	38.9

Fort Liscum.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	45	45	54	53	71	79	82	80	84	57	47	45	.....
Minimum	−14	−12	− 8	2	25	30	32	30	17	10	0	−13	.....
Mean	20.7	21.8	26.1	27.8	41.8	49.8	52.0	50.1	44.9	35.8	29.1	23.9	35.2

Juneau.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	50	51	61	63	80	84	88	82	74	68	60	60	.....
Minimum	−10	− 4	− 5	13	24	31	38	36	23	20	− 1	1	.....
Mean	26.9	29.2	34.7	41.0	48.4	54.8	58.1	55.4	49.6	43.6	34.7	31.9	42.6

Killisnoo.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	52	50	53	63	76	83	84	81	69	65	65	54	.....
Minimum	− 7	−10	− 2	15	44	31	38	36	27	10	1	1	.....
Mean	27.4	26.9	32.8	38.6	45.8	51.3	55.2	54.4	48.0	41.7	33.8	31.1	43.1

Kodiak.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	53	58	65	61	74	82	82	85	77	66	54	61	.....
Minimum	− 8	− 3	2	5	20	30	32	34	26	16	9	−12	.....
Mean	29.4	22.7	33.7	36.1	43.4	50.3	54.1	59.4	46.9	41.6	29.8	30.5	40.5

Loring.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	47	52	63	67	93	91	87	85	83	67	58	54	.....
Minimum	−20	−23	−10	9	25	32	36	35	30	15	5	4	.....
Mean	23.2	29.8	34.0	39.5	48.5	53.0	57.3	57.1	51.2	43.9	36.4	32.1	42.8

Seward.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	43	44	49	65	75	84	83	85	84	64	49	45	.....
Minimum	−11	−12	− 7	10	26	32	40	33	27	11	9	−10	.....
Mean	19.0	27.0	31.3	36.5	43.5	45.8	54.1	54.4	48.7	39.0	31.1	25.8	39.5

Sitka.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	56	58	65	70	80	84	87	83	80	70	60	59	.....
Minimum	− 4	− 3	− 1	15	28	30	34	30	28	22	1	5	.....
Mean	31.7	33.5	36.5	41.3	46.7	51.2	54.7	57.2	51.8	45.7	38.0	35.6	43.8

Skagway.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	47	49	63	62	94	90	92	89	77	63	56	57	.....
Minimum	−21	− 9	−10	9	25	29	37	31	26	12	− 6	− 4	.....
Mean	18.4	24.0	30.2	40.0	49.5	56.0	58.2	54.3	49.6	40.8	31.2	26.9	39.6

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Summary of temperature records at various Weather Bureau stations in southern Alaska—Continued.

Sunrise.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	44	57	58	60	76	79	76	78	72	59	51	48	.....
Minimum	−29	−27	−23	−4	23	27	34	28	17	2	−15	−26	.....
Mean	10.4	19.4	24.9	33.0	43.1	49.8	53.6	51.6	44.3	34.1	22.6	17.7	33.5

Tyonek.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	38	49	58	59	74	91	82	76	79	61	47	49	.....
Minimum	−27	−25	−9	−1	22	33	38	31	22	5	−3	−21	.....
Mean	11.5	18.6	25.3	35.2	45.2	53.4	57.0	58.3	48.9	36.2	25.2	18.5	36.1

Valdez.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	44	47	52	63	78	78	84	84	82	62	53	45	.....
Minimum	−2	−17	−6	4	18	30	37	29	30	12	1	−6	.....
Mean	19.2	22.4	26.7	34.4	43.5	50.0	53.9	52.7	47.8	40.5	26.4	22.3	35.8

As would be expected from its position north of the coast range, the greatest range in temperature occurs at Copper Center, whereas all the other stations are within the Pacific coast province. At that point there is a variation of 170°, ranging from a maximum of 96° in June to a minimum of —74° in January. A mean annual temperature of 27.1 shows clearly the rigorous climatic conditions.

An interesting relation between the coast stations is the narrow range in the mean annual temperature. The extreme difference is only 10.3°, the maximum of 43.8 occurring at Sitka and the minimum 33.5 at Sunrise.

Temperatures below zero have been recorded at all the stations except Cordova, where 1° is the minimum. At that station the minimum yearly range of 85° also occurs. The most uniform mean monthly temperatures occur at Sitka, ranging from 31.7° for January to 57.2° in August.

CONTROLLER BAY REGION.

GENERAL FEATURES.

The Controller Bay region occupies an area about 500 square miles in extent, bounded by the Chugach Mountains on the north, Bering Glacier on the east, the Pacific Ocean to the south, and the Copper River delta on the west.

The topographic features of the region are exceedingly varied, including southern spurs from the Chugach Mountains, isolated peaks to the south ranging in height from 1,000 to 3,000 feet, with intervening low swampy areas and numerous lakes.

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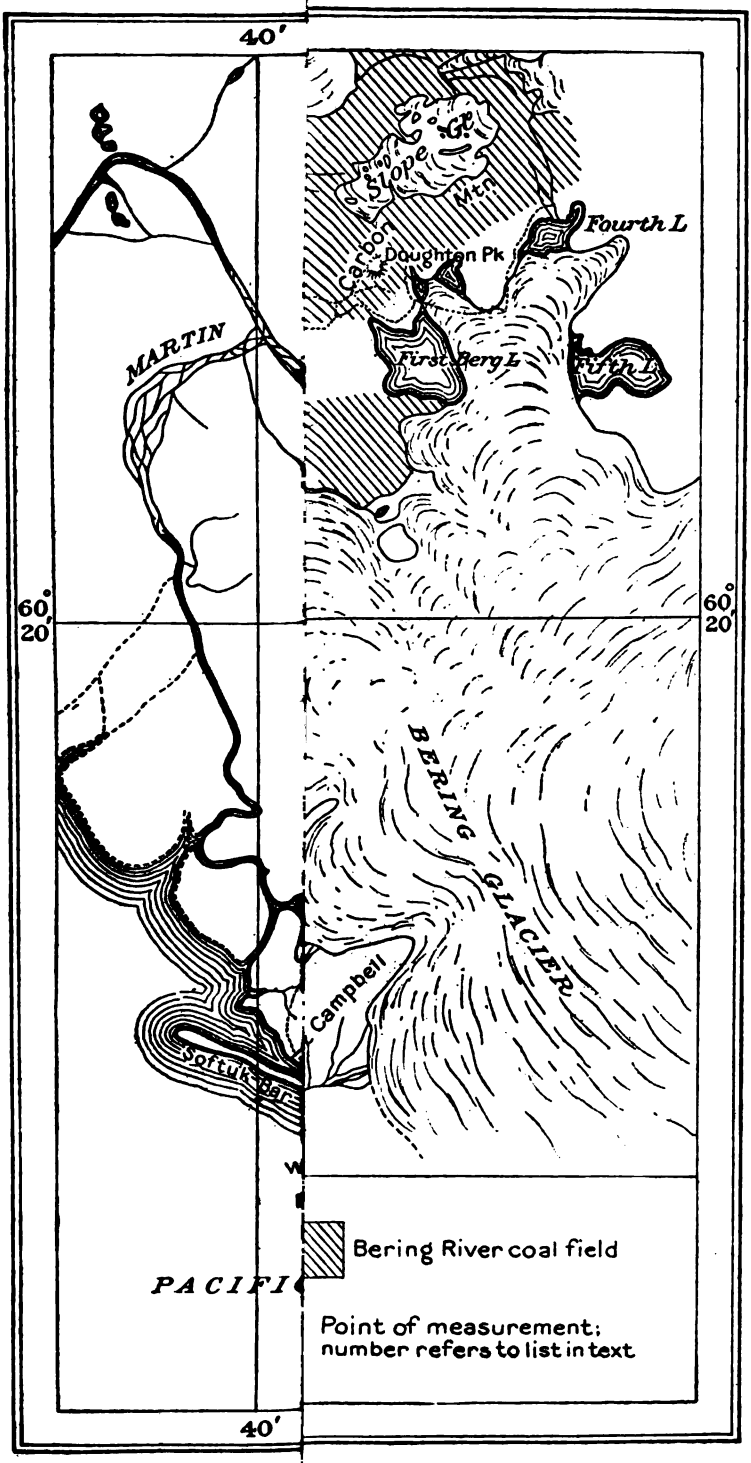

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Katalla, the post office and commercial center of the region, is on the north shore of Katalla Bay about 10 miles east of Controller Bay. Supplies are landed by small launches from ocean-going vessels, which anchor about half a mile from the shore. Katalla is a proposed outlet for the Bering River coal field which lies 20 to 30 miles northeast of the town.[1]

Little information is available regarding the climate of this region. (See p. 15.) The average yearly precipitation probably exceeds 100 inches and snowfall is rather heavy. The summers are cool and cloudy and the winters are moderate.

Spruce and hemlock, the principal trees, grow in heavy stands and reach diameters of 2 to 3 feet. The best timber grows along the foothills below an elevation of 1,000 feet. The United States Forest Service estimates the stands on the Ragged Mountains and in the vicinity of Martin River and Bering Lake at approximately 2,130,000,000 feet board measure.

MEASURING POINTS.

The points at which discharge measurements were made in 1913 in the Controller Bay region are listed below. Records of daily flow are not available for streams in this region. The numbers in the list correspond to numbers on Plate II.

Measuring points in Controller Bay region, 1913.

1. Bering River above Stillwater Creek.
2. Canyon Creek at mouth.
3. Stillwater Creek 1 mile above mouth.
4. Trout Creek one-fourth mile above mouth.
5. Clear Creek at Cunningham's camp.
6. Clear Creek near Katalla.

BERING RIVER DRAINAGE BASIN.

GENERAL FEATURES.

Bering River drains the eastern part of the Controller Bay region, of which it is the principal stream. Its water is derived mainly from Bering Glacier, though Martin River Glacier contributes considerable water through Canyon, Stillwater, and Shepherd creeks. As in most glacial streams the volume of discharge bears little relation to the area of the drainage basin, which is indeterminate because of uncertainty as to how much of Bering and Martin River glaciers drains through Bering River.

Bering River rises in First Berg Lake (see Pl. II), the first of a series of five lakes on the northeast margin of Bering Glacier. It flows

[1] The Bering River coal field is described by G. C. Martin, Geology and mineral resources of the Controller Bay Region, Alaska: U. S. Geol. Survey Bull. 335, pp. 65-112, 1908. The Controller Bay oil field is described in the same bulletin, pp. 112-120.

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southwestward about 23 miles and enters the northern part of Controller Bay about 10 miles west of Katalla. The areas of the lakes from first to fifth are 2.2, 0.08, 0.27, 0.58, and 1.8 square miles, respectively. These lakes have been described by Martin[1] as follows:

Marginal lakes.—The five Berg Lakes, situated on the margin of Bering Glacier, near the northeast corner of the region under discussion, present some interesting features. These lakes are bordered on their landward sides by steep banks, which are in general barren of vegetation and which are covered chiefly with glacial débris. These banks extend to an elevation of about 1,000 feet above tide, or about 200 feet above the level of the lakes. They are cut and built into well-developed terraces, which mark former stages in the elevation of the lakes. The lower terraces are entirely barren of vegetation, but the upper ones have a scant growth of grass, herbs, and small bushes, which are only a few years old.

The surface of the four western lakes is known to be at the same altitude (about 810 feet in 1905), and Fifth Lake probably is at the same level.

These lakes are certainly connected by water channels through the crevasses of the glacier, and possibly by open spaces under the ice. The surface of the ice is level, except where it rests against the land on the points between the lakes. The identity in the altitude of the lakes, the level surface of the ice between the lakes, and the way in which bergs break off on the margin of First Lake show that this arm of the glacier is floating in one large lake, of which the five Berg Lakes are only open areas. The surface of the glacier, after a gentle slope, descends in a low, crevassed icefall to its floating level.

The level of the lake is oscillating. The absence of vegetation on the lower terraces shows that it has fallen in recent years. In June, 1905, it was rising several inches per day. The outlet of the lake, which is beneath the ice at the end of the long point south of First Lake, becomes choked with débris at irregular intervals. The water then rises until the pressure clears the outlet or till the water can flow on the surface around the end of the point, when the lake is emptied, causing severe floods in the valley of Bering River.

The principal tributaries of Bering River from the north are Canyon, Stillwater, and Shepherd creeks. Gandil and Nichawak rivers flow from Bering Glacier through a low swampy country and enter Bering River from the east below Bering Lake.

Bering Lake, which lies about 5 miles north of Controller Bay, covers an area of about 12 square miles and is said to be very shallow. It is connected with Bering River by several channels, though most of the river water passes by without entering the lake. The level of the lake is raised from 1 to 3 feet by tides.

Bering River is navigable for small launches during high and medium stages as far as the mouth of Stillwater Creek, a distance of 16 miles. It flows over a bed of glacial sand and silt with constantly changing channels.

First Berg Lake lies at an elevation of about 800 feet. About 2 miles below the lake, at an elevation of about 750 feet, the river commences to fall rapidly (see Pl. III, *A*) and in a distance of less than a mile it drops over 600 feet. Power could be developed by

[1] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 47–48, 1908.

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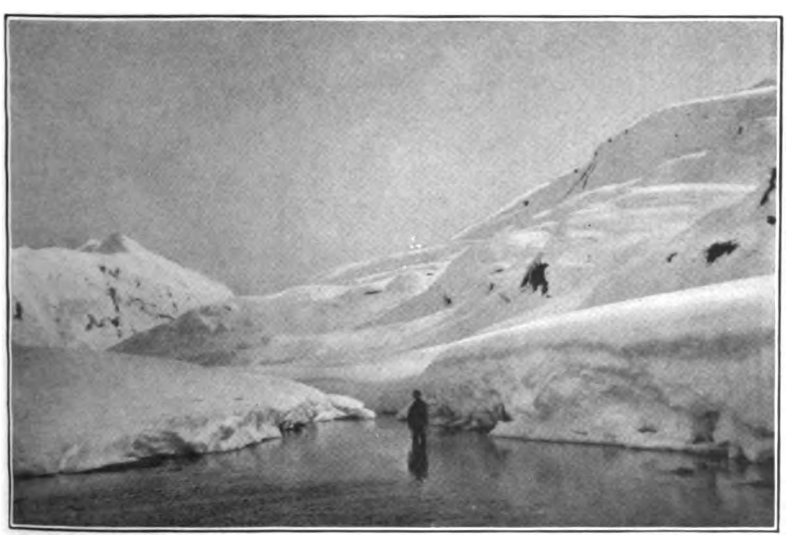
A. FALLS ON BERING RIVER NEAR OUTLET OF FIRST BERG LAKE.

Ice cliff from Bering Glacier in background.



B. SOLOMON GULCH, MAY 9, 1913.

Elevation, about 600 feet.

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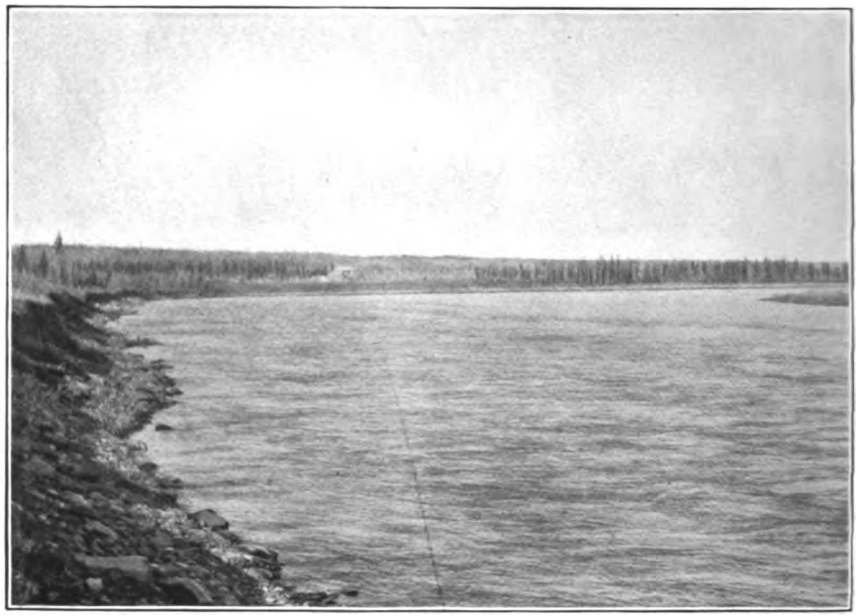
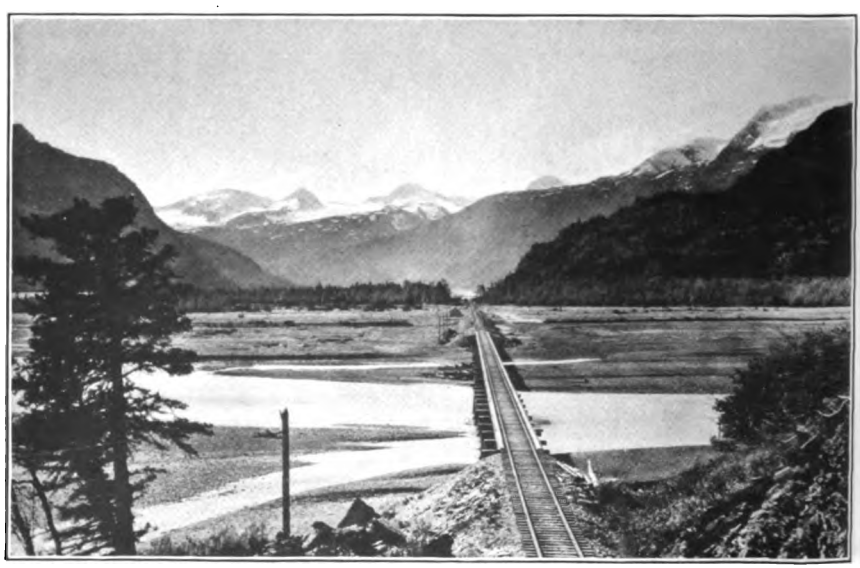


A. COPPER RIVER 1 MILE ABOVE COPPER CENTER.



B. COPPER RIVER VALLEY.

Tiekel River in foreground.

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carrying water from First Berg Lake through Carbon Mountain to Canyon Creek valley, where a head of about 650 feet could be obtained. A tunnel about 1 mile long would be required. It would not be possible to raise the level of the lake by a dam because of the glacier which obstructs the outlet, but substorage could be obtained by placing the intake below the low-water level of the lake. According to Martin the lake is subject to changes in level, due to obstructing of the outlet by débris. He also states that it has fallen in recent years.

Careful observations of the lake level should be taken at frequent intervals for a year or more before beginning the construction of a tunnel or other form of conduit to divert the water from the lake.

On July 10, 1913, the lake was still frozen over from the previous winter. It is reported that it has been known to remain frozen throughout the summer.

A measurement of Bering River made just above Stillwater Creek on July 11, 1913, gave a discharge of 3,950 second-feet. A simultaneous measurement of Canyon Creek showed a discharge of 179 second-feet. The inflow between Canyon Creek and the lake outlet appears to be rather small. It is believed that an estimate of 3,000 second-feet discharge at the lake outlet on the above date is conservative, though it is open to question because of the possibility that considerable inflow that could not be seen may reach the river below the lake.

A flow of 3,000 second-feet under a head of 650 feet, would develop over 155,000 horsepower with an efficiency of 70 per cent at the wheel. The measurement was made in the season of maximum run-off, and as no winter records are available it is difficult to estimate the amount of power that could be developed during that season; but since with the head available (650 feet) over 5,000 horsepower could be produced for every 100 second-feet of discharge, it seems conservative to predict, considering the feasibility of drawing on storage from the lakes, that at least from 5,000 to 10,000 horsepower could be produced throughout the year.

CANYON CREEK.

Canyon Creek rises in Martin River Glacier, flows southward about 6 miles, and enters Bering River 6 miles below First Berg Lake. The creek falls 900 feet, thus having an average grade of about 150 feet per mile.

The first 3 miles of its course is through a narrow, steep-walled valley, which becomes wider with approach to Bering River and at the junction reaches a maximum of more than a mile.

A measurement made July 11, 1913, gave a discharge of 179 second-feet.

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STILLWATER CREEK.

GENERAL FEATURES.

Stillwater Creek rises in Kushtaka Lake, flows southeastward about 4 miles, and enters Bering River about 2½ miles below Canyon Creek. Its total fall is approximately 60 feet. For the last mile of its course the current is rendered very sluggish by backwater from Bering River.

Its principal tributaries are Trout and Clear creeks, clear-water streams that flow from Cunningham Ridge and enter from the north about 1 mile below Kushtaka Lake.

Kushtaka Lake is nearly 4 miles in maximum length, trends northeast-southwest, and covers an area of 4.7 square miles. Practically the entire inflow is from Kushtaka Glacier, which is a southern arm of Martin River Glacier. The lake acts as a settling basin, thus giving a much clearer outflow than the ordinary glacial stream.

The level of the lake could be raised 20 to 30 feet by a dam of moderate length, thus obtaining a storage of 60,000 to 90,000 acre-feet. A fall of at least 35 feet below the normal lake level could be obtained by carrying the water in a pressure pipe for a distance of about 1 mile. Under that head, with an efficiency of 70 per cent, about 275 horsepower could be realized at the wheel for every 100 second-feet of discharge. The only data regarding the flow is one discharge measurement listed below. Considering the storage that could be created it is estimated that from 500 to 1,000 horsepower could be developed at minimum flow in the winter and from 1,000 to 2,000 horsepower from May until October.

The lake is confined by morainic material deposited by Martin River Glacier when at its maximum extension. The nature of the foundation that could be obtained for a dam at the outlet is unknown. The material at the surface resembles heavy glacial till. A solid rock foundation might be obtained at a moderate depth.

DISCHARGE MEASUREMENTS.

The following miscellaneous measurements were made in Stillwater Creek drainage basin in 1913:

Miscellaneous measurements in Stillwater Creek drainage basin in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Second-feet.	*Square miles.*	*Second-feet.*
July 11	Stillwater Creek	Bering River	1 mile above mouth	858	.....	.....
11	Trout Creek	Stillwater Creek	½ mile above mouth	12.6	2.3	5.48
11	Clear Creek	do	Cunningham's camp	37	6.3	5.87

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KATALLA RIVER.

Katalla River drains an area of 38 square miles west of Bering Lake. It is about 8 miles long and flows in a southeasterly direction, entering Katalla Bay at the town of Katalla. The valley is low and swampy and is more than a mile in average width. The headwaters are separated from Bering Lake by a divide less than 100 feet in elevation. The natural railroad route from Katalla to the coal fields lies up the Katalla River valley and over the divide to Bering River.

Clear Creek, the principal tributary of Katalla River, joins it from the north about a mile from Katalla. It is about 4 miles long and drains an area of 7.5 square miles. It occupies a narrow, V-shaped valley and flows through a succession of pools and rapids over a bed of gravel and bowlders, with a grade of about 150 feet per mile.

The following measurement was made 1 mile above the mouth:

July 13, 1914: Discharge, 151 second-feet; drainage area, 6.8 square miles; discharge, per square mile, 22.1 second-feet.

WATER-POWER SITES.

The principal water-power sites in the Controller Bay region are on Bering River at the outlet of First Berg Lake (p. 36), and on Stillwater Creek at Kushtaka Lake outlet (p. 38). Some of the smaller streams might furnish a few hundred horsepower for 5 or 6 months in the year, but it is doubtful whether storage could be provided for the development of more than very small power in the winter.

The only market that can be foreseen for these powers is the energy that will eventually be required in connection with the mining of the coal beds of the area. Coal of good quality will then be available at comparatively low cost, and the poorer qualities unsuited for the open market will offer a fuel for local power development so cheap that water power will have to be produced in the most economical manner to become a successful competitor.

COPPER RIVER DRAINAGE BASIN.

GENERAL FEATURES.

The Copper River drainage basin occupies an area comprising about 23,000 square miles in the southeastern part of the main body of Alaska. It may be divided into four physiographic divisions—the Chugach Mountains on the south, the Wrangell Mountains on the east, the Alaska Range to the north, and the Copper River Plateau to the west.

The topography of the basin is of the most varied character. The Wrangell Mountains, occupying the northeastern section, form the

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most conspicuous feature. They have been described by Moffit and Capps [1] as follows:

The Wrangell Mountains, although a more or less distinct group, merge into the St. Elias Range on the southeast and are not there sharply defined from them. They are limited on the south and west and partly on the north by the valleys of Chitina and Copper rivers, and are separated from the Nutzotin Mountains on the northeast by a depression extending from the head of Copper River to the head of White River. The group trends in a northwest-southeast direction and its length is approximately double its width. Its greatest diameter is about 100 miles. Half a dozen or more peaks of unusual beauty and size, ranging in height from 12,000 to 16,200 feet, rise above the rugged snow-covered mass about them, and from one of these, Mount Wrangell, the group received its name. The Wrangell Mountains were formed by the erosion of a great mass of Tertiary and Recent lavas piled up on an older sufface of very considerable relief and having its greatest development in the neighborhood of Mount Wrangell and Mount Sanford. The southeastern limit of these younger flows is probably somewhere in the vicinity of Skolai Pass and Chitistone River, although it is possible that they may extend still farther to the east. Thus the Wrangell Mountains consist essentially of lava flows and are distinct in their origin from the other mountains about them, all of which are made up principally of deformed sedimentary beds.

The most prominent summits are Mount Sanford (16,208 feet), Mount Blackburn (16,140 feet), Mount Wrangell (14,005 feet), Mount Regal (13,400 feet), and Mount Drum (12,000 feet).

The range is covered with a connected system of glaciers whose tentacle-like arms spread out from the various peaks and reach down at numerous points to elevations of 2,000 to 4,000 feet, from which flow many important streams. Kennicott Glacier terminates at an elevation of about 1,500 feet, the lowest elevation reached by any of the ice sheets draining to the Chitina River or the Copper above the Chitina.

The Copper River Plateau has been described by Brooks [2] as follows:

A broad gravel and silt floored basin stretches north from the inland slope of the Chugach Mountains to the foothills of the Alaska Range. It is bounded on the east by the Wrangell Mountains and the Copper River, and extends westward to the Susitna basin by a depressed area lying between Talkeetna Mountains and the Alaska Range. The basin has a monotonous lack of relief which contrasts strongly with the rugged mountains encircling it. [See Pl. IV, *A*, p. 37.] At the escarpment on its eastern margin where it falls off to the Copper River it stands about 2,000 feet above sea level, but it rises gently to the west to an altitude of about 3,000 feet at the divide. This topographic feature is, in fact, a plateau built up largely of Pleistocene deposits, deeply dissected near its margins and called the "Copper River Plateau," by Mendenhall,[3] who was the first to describe it. While it is usually an almost unbroken plain, it is varied in places by hills and small groups of mountains and is dotted with small lakes.

[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 10, 1911.

[2] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 54, 1906.

[3] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 297, 1900.

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The Copper River Plateau lies entirely within the Pacific mountain system, and though of low relief includes three important watersheds. Its eastern drainage falls into the Copper, its western into the Susitna and Matanuska, and a small area in the north drains to the Tanana through the Delta River.

Within the plateau region the Copper River and its tributaries have cut deep channels varying from a few feet up to 500 or 600 feet below the general plateau level. (See Pl. IV, *A*, p. 37.) The formation is made up largely of sand, gravel, and clay, and it is not likely that many solid rock canyons occur except possibly near the headwaters of the stream flowing from the Wrangell Mountains.

Copper River rises in Copper Glacier on the north slope of Wrangell Mountain and enters the Pacific about 150 miles (in an air line) south. Mount Sanford (elevation 16,208 feet), the highest peak of the Wrangell Range, lies about 10 miles to the west of the Copper Glacier outlet. Nabesna Glacier, situated about 30 miles farther east, is one of the sources of the Tanana River. Copper River flows in a northerly direction for about 40 miles to its junction with the Slana, a large tributary from the north. Batzulnetas is situated at the mouth of Tanada Creek, 10 miles above the Slana. After receiving the Slana, the Copper makes a right-angle turn to the west, gradually bending to the south, and then, bearing toward the east, it is joined from the east by its largest branch, the Chitina, about 150 miles below its head. It has then nearly encircled the western end of the Wrangell Mountains. The town of Chitina is on the west side of the Copper opposite the mouth of the Chitina River.

Below Chitina the Copper enters the Chugach Range and thence to its mouth its flood plain reaches to steep mountain slopes on either side, broken only by some of its larger branches from the east and west, which, heavily laden with glacial sand and gravel, have built up terraces at their mouths. (See Pl. IV, *B*.) Between Chitina and Tasnuna rivers the flood plain is seldom over a mile in width and averages much less than that. At Wood Canyon, beginning about 6 miles below Chitina, the river passes between narrow rock walls for about 3 miles. At several points the canyon is of the "box" type, with nearly vertical sides rising 50 feet or more above the water surface. This canyon offers probably the most natural site for power development on Copper River. Below the Tasnuna the valley floor widens and for much of the remainder of its course to the delta is 1 to 4 miles wide.

Abercrombie Rapids are situated along the northern part of the terminal moraine from Miles Glacier. It is estimated that in a distance of about 2.5 miles the river falls through a height of about 40 feet. The rapids were probably formed by the former encroachment of the glacier upon the river channel. The carrying power of the river above the glacier was thereby decreased, and heavy deposits

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of glacial sediment were laid down, forming a lower stream-gradient for several miles above. When the glacier began to recede it left large bodies of heavy till, through which the river is now slowly cutting its way. The river has been pushed well over toward the west side of the valley and hugs the base of steep rocky slopes for the first 2 miles of the rapids. It then makes a nearly right-angle turn to the east and about one-half mile farther on enters an expanded section of the river at the base of Miles Glacier, known as Miles Glacier Lake.

Abercrombie Rapids offer the fundamental requirements for the development of power, a large volume of water and a concentrated fall. The economic value of a water power, however, depends on the market for the power and the cost of development. The latter factor alone would probably put this site out of the class that would be economically feasible at the present time and probably far into the future. The principal difficulty would be the construction of a diversion dam. A rock foundation probably could not be obtained at a reasonable depth. The east end of the dam would be in a high glacial moraine which is probably underlain with ice. (See Pl. V, *A*.) The track of the Copper River & Northwestern Railway follows the west bank of the river past the rapids. To carry water from the head of the rapids to a power house at the foot, nearly 2 miles of tunnel would have to be built through the rock slope on the west side of the river in order to avoid the railway track. The eastern slope, which is flanked by the moraine, would offer a distinctly unstable foundation for a conduit even though the water could be successfully diverted.

Copper River carries large quantities of frazil during October and November when it is freezing. In the spring, beginning about the first of May, the break-up occurs, during which time there is an immense flow of heavy cakes of ice that would be difficult to pass over a dam. The large quantities of glacial débris that are carried by the river would also present a serious problem if power development should be undertaken.

Twenty-five miles below the Slana Copper River is joined by Chistochina River, which rises in the Alaska Range on the south slope of Mount Kimball and flows south about 50 miles. Here Copper River emerges from the valley between the Alaska Range and the Wrangell Mountains and flows along the eastern margin of the Copper River Plateau until it approaches the Chitina. Between the Chistochina and the Chitina the principal tributaries of the Copper in downstream order from the north and west are the Gakona, Gulkana, Tazlina, Klutina, and Tonsina rivers; from the east it receives the Sanford, Klawasi, Nadina, Dadina, Chetaslina, Cheshnina, and Kotsina rivers, which drain the westward slope of the Wrangell Mountains.

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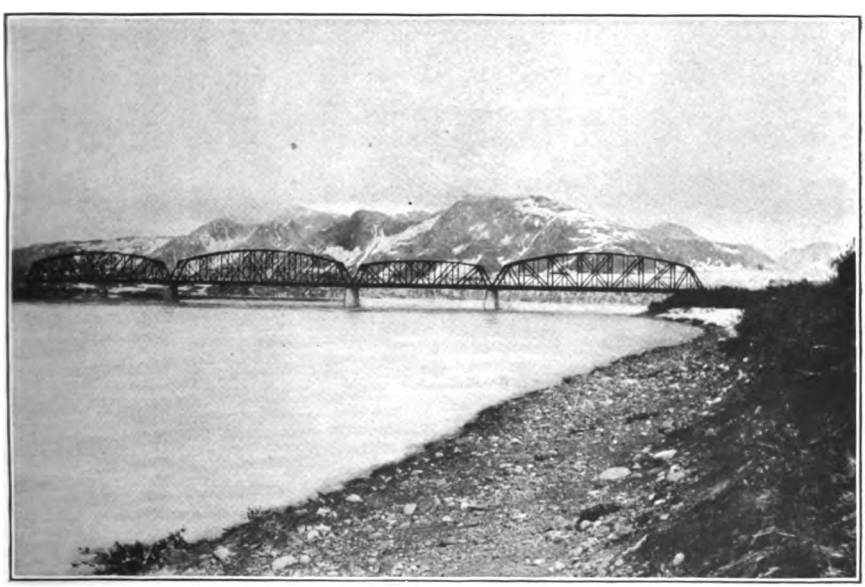
A. COPPER RIVER, LOOKING DOWNSTREAM TO HEAD OF ABERCROMBIE RAPIDS.

Moraine from Miles Glacier on the left. Copper River & Northwestern Railway follows right bank.



B. VIEW UP COPPER RIVER. MILES GLACIER IN THE BACKGROUND.

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Below Chitina the principal tributaries are Tasnuna and Tiekel rivers from the west and the Bremner from the east.

The delta begins about 10 miles below Miles Glacier, 30 miles from salt water. Alaganik Slough, the westernmost channel, enters salt water about 12 miles southeast of Cordova. Eastward many channels reach the ocean for a distance of over 20 miles.

"The lower course of the Copper seems once to have been a wide embayment reaching back into the Chugach Mountains, but this has been filled in by vast quantities of sediment brought down by the river, and the broad delta is the result of their deposition."[1]

Nearly all the tributaries of the Copper head in glaciers and carry heavy deposits of glacial silt (see table, p. 46), particularly during the warmer months, when they are especially active. Only two "live" glaciers—Miles and Childs—reach the main river. They are situated about 30 miles from salt water. Miles Glacier is on the east bank just above the crossing of the Copper River & Northwestern Railway (see Pl. V, *B*), and Childs Glacier is just below on the opposite side. Large quantities of ice break from the face of these glaciers into the river during warm weather. Childs Glacier appears the more active of the two. Each presents a face of about 2 miles along the river's edge, in some places rising vertically more than 300 feet above the water's surface.

Before the construction of the Copper River & Northwestern Railway from Cordova to Chitina and Kennicott small boats were used quite extensively on the Copper and some of its larger tributaries, and light-draft steamboats have navigated from the Tasnuna to Copper Center and from Chitina to the Nizina River on the Chitina. Since the railroad has been in operation little boating has been done on the Copper, and the construction of roads and trails and a fuller knowledge of the tributary areas has lessened the advantage of using the minor stream for boating.

Copper River rises at an elevation of about 3,600 feet, making an average gradient of about 12 feet per mile. From Copper Center to the ocean there is a total fall of 1,000 feet, giving a mean fall in that distance of about 6.7 feet per mile.

MINERAL RESOURCES.

The principal mineral resources of the Copper River basin are copper and gold. The most important copper deposits are those of the Kotsina-Chitina[2] belt, extending along the southern slope of the Wrangell

[1] Schrader, F. C., and Spencer, A. C., Geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey special reports on Alaska, p. 27, 1901.

[2] Described by Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 42-92, 1909; Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 77-97, 1911. See also Moffit, F. H., Mining in Chitina Valley: U. S. Geol. Survey Bull. 542, pp. 81-85, 1913.

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Mountains from Kotsina River to the headwaters of Nizina River. Considerable development work has been done on several veins, but the only productive mine is the Kennicott-Bonanza,[1] near the eastern end of the belt, about 200 miles from Cordova, at the terminal of the Copper River & Northwestern Railway.

Gold-bearing quartz veins have been discovered in the McKinley Lake district near Alaganik;[2] near mile 109 along the Copper River Railroad; at several localities in the headwaters of Tiekel River; on the south slope of the Wrangell Mountains near Strelna; and at several points in the Nizina River basin. Considerable development work has been done on these veins, but no mines have yet reached a productive stage.

Two important gold placer districts, the Chistochina[3] and Nizina,[4] occur in the Copper River basin. Promising placer deposits have recently been discovered on headwater tributaries of the Tazlina River. Placer gold has also been discovered on the Bremner[5] and Tiekel rivers.

TIMBER.

The following description of the timber resources of the Copper River basin, by Alfred H. Brooks, is taken from the report of the Alaska Railroad Commission:[6]

Timber.—The lowlands stretching eastward from Cordova to the Copper River Delta are in part timbered. Timber is not very abundant and occurs in isolated tracts. The largest trees in this part of the district are not over 2 or 3 feet in diameter. The forests are chiefly of spruce and hemlock, and timber extends to an altitude of about 3,000 feet, but that useful for commercial purposes is chiefly in the lowland.[7] There is no timber between the Copper River Delta and the mouth of the Tiekel. The only exception is some scrub spruce at a few localities and a growth of stunted cottonwood which occurs on some of the islands in the river and adjacent flats.

Above the Tiekel spruce timber occurs sparingly along the lower slopes of the valley, but there is none of it of any value until the mouth of the Chitina is approached. There is some excellent timber along the west side of the Copper River near Chitina, where trees up to 2 feet in diameter occur. A small growth is found at various places along the Copper River and its tributaries, but this heavy timber all occurs in the valley bottoms of the larger streams. The aggregate areas of good forest is small. The so-called Copper River Plateau, which stretches northward from the coast range to the foot of the Alaska Range, is covered with stunted spruce, together with some white birch and cottonwood. On the slopes of the valleys which traverse this region some better spruce timber is found but occurs only in small quantities. Fairly good timber occurs along the southern foothills of the Alaska Range, where trees from 12 to 18 inches in diameter are found. * * *

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[1] See Moffit and Maddren, op. cit., pp. 80-86.

[2] Chapin, Theodore, The McKinley Lake district: U. S. Geol. Survey Bull. 542, pp. 78-80, 1913.

[3] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 70-80, 1912.

[4] Moffit and Capps, op. cit., pp. 100-108.

[5] Moffit, F. H., The Taral and Bremner River districts: U. S. Geol. Survey Bull. 520, pp. 95-101, 1912; The Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 43-49, 1914.

[6] Report of Alaska Railroad Commission, 62d Cong., 3d sess., H. Doc. 1346, p. 74, 1913.

[7] Those stands in the vicinity of Eyak Lake and River and Sheridan Glacier are approximately estimated by the Forest Service to contain a total of 425 to 635 million feet board measure.

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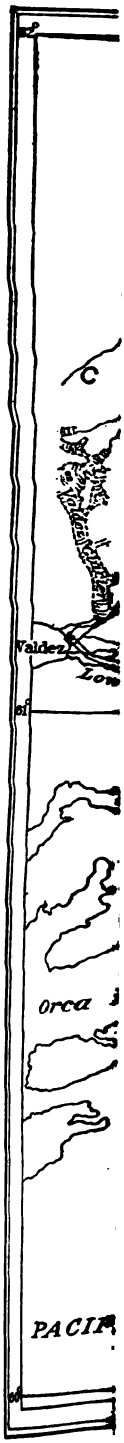

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From Chitina eastward the Kennicott extension of the railway traverses a gravel bench standing 300 to 500 feet above the river level, and this is covered with a similar type of vegetation to that of the Copper River Plateau. The trees are mostly stunted and have no value except for fuel. There are some patches of good timber in the river bottoms along the Lakina and other streams.

GAGING STATIONS AND MEASURING POINTS.

The points at which gaging stations were maintained or discharge measurements made in 1913, in the Copper River basin, are listed in the following table. The numbers correspond to those used on Plate VI.

Gaging stations and measuring points in Copper River basin in 1913.

1. **Copper River near Copper Center.**
2. **Copper River at Miles Glacier.**
3. **Klutina River at Copper Center.**
4. Kotsina River near mouth.
5. Nizina River above Kennicott River.
6. Dan Creek above hydraulic plant.
7. White Creek above Jolly Gulch.
8. Chititu Creek below Rex Creek.
9. Rex Creek above hydraulic plant.
10. McCarthy Creek above Nikolai Creek.
11. **McCarthy Creek near McCarthy.**
12. Lakina River at railroad crossing.
13. Gilahina River at railroad crossing.
14. Chokosna River at railroad crossing.
15. Kuskulana River at railroad crossing.
16. Strelna Creek at railroad crossing.
17. Tsina River below Ptarmigan Creek.
18. Tsina River at mouth.
19. Tiekel River at mouth.
20. Ptarmigan Creek at upper canyon.
21. Ptarmigan Creek at lower canyon.
22. Stuart Creek at mouth.
23. Kanata River at mouth.

NOTE.—Black-faced type indicates regular gaging stations; light-faced type points of miscellaneous measurements.

COPPER RIVER NEAR COPPER CENTER.

A temporary gage was installed on Copper River at the Indian School about 1½ miles above Copper Center June 18, 1913.

Two readings of stage and one of turbidity were taken each day from June 18 to November 30. No means were available for making discharge measurements, but it would be possible to stretch a light cable across the river at Copper Center in holding in place a boat from which soundings and velocity measurements could be made. On September 27, 1913, the river at the suggested measuring section was 330 feet wide, and a measurement made by dropping floats across the section at intervals of 25 feet gave a mean surface velocity of 6.43 feet per second.

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Daily gage height, in feet, of Copper River near Copper Center for 1908.

[Chas. W. H. Heideman, observer.]

Day.	May.	June.	July.	Aug.	Day.	May.	June.	July.	Aug.
1	2.0	3.2	5.1	3.6	16	1.6	3.6	5.2	3.1
2	2.0	4.0	5.1	3.9	17	3.0	.....	5.0	3.0
3	2.0	4.4	5.0	4.0	18	5.2	4.0	4.9	2.9
4	[a] 4.1	4.7	4.8	4.0	19	5.6	4.0	4.9	3.0
5	4.9	4.2	4.8	4.0	20	5.9	5.0	5.1	3.0
6	5.0	3.5	4.8	4.0	21	6.4	5.1	5.1	3.1
7	5.6	3.7	4.7	4.0	22	5.9	5.1	5.0	3.2
8	6.0	3.3	4.6	3.8	23	.....	5.1	5.0	3.3
9	6.1	2.9	4.7	3.7	24	4.6	5.2	5.0	3.2
10	[a] 4.2	3.2	4.9	3.6	25	4.1	5.1	5.0	3.2
11	.8	3.2	5.2	3.5	26	3.9	5.1	3.7	3.0
12	.8	3.1	5.7	3.2	27	3.3	5.1	3.6	2.9
13	.8	3.0	5.4	3.2	28	3.4	5.2	3.8	3.0
14	.6	3.5	5.2	3.3	29	3.1	5.1	3.8	3.3
15	[b] 2.0	3.6	5.0	3.2	30	3.0	5.0	3.5	3.5
					31	2.4	.....	3.5	.....

[a] Ice jammed below gage from May 4 to 10. Ice went out 1 p. m. May 10.
[b] Ice running.

NOTE.—Records furnished by Mr. Heideman, who was in charge of the Government experiment farm. The exact location of the gage is not known but was probably near the one installed in 1913. Ice went out May 5, 1907.

Daily gage height, in feet, and turbidity, in parts per million,[a] of Copper River near Copper Center, Alaska, in 1913.

[L. A. Jones, observer.]

Day.	June.	July.		August.		September.		October.		November.	
	Gage height.	Gage height.	Turbidity.	Gage height.	Turbidity.	Gage height.	Turbidity.	Gage height.	Turbidity.	Gage height.	Turbidity.
1	.....	17.6	.....	19.5	1,500	15.2	350	14.3	150	13.0	120
2	.....	17.4	.....	18.7	1,500	15.0	250	14.3	110	13.0	130
3	.....	17.4	.....	18.1	1,500	15.0	180	14.2	150	13.0	130
4	.....	17.6	.....	17.6	800	14.8	200	14.2	110	12.8	130
5	.....	18.0	.....	17.4	800	14.7	200	14.1	130	12.8	120
6	.....	18.6	1,500	17.3	500	14.6	180	14.0	130	12.8	120
7	.....	18.5	900	17.2	800	14.5	180	14.0	130	12.8	110
8	.....	18.4	800	17.0	800	14.4	200	13.8	130	12.7	110
9	.....	18.1	600	16.8	600	14.3	180	13.6	130	12.6	110
10	.....	17.8	600	16.7	500	14.2	180	13.6	130	12.6	110
11	.....	17.8	600	16.6	800	14.1	180	13.4	110	12.6	100
12	.....	17.6	500	16.3	500	14.0	180	13.3	110	12.6	100
13	.....	17.4	350	16.2	500	14.0	180	13.4	110	12.6	85
14	.....	17.3	400	16.2	500	13.9	180	13.6	130	12.7	95
15	.....	17.3	400	16.1	800	13.9	110	14.0	130	12.8	85
16	.....	17.4	500	15.9	600	13.9	100	13.8	150	12.7	85
17	.....	17.2	500	15.8	500	13.8	110	13.7	150	12.6	100
18	16.7	17.0	500	15.6	500	13.8	110	13.6	150	12.8	95
19	17.0	16.9	350	15.6	500	13.7	130	13.4	150	12.6	100
20	17.0	16.5	300	15.8	350	13.7	100	13.6	150	12.5	95
21	16.8	16.5	400	16.0	500	13.7	100	13.5	150	12.5	95
22	16.7	16.4	300	16.1	800	13.7	100	13.5	130	12.5	80
23	17.0	16.6	350	16.0	800	13.7	120	13.5	130	12.5	85
24	17.8	16.8	350	16.2	800	14.0	110	13.4	130	12.6	80
25	18.1	17.3	400	16.5	800	14.4	150	13.2	130	12.6	85
26	18.0	18.4	1,500	16.7	800	14.5	250	13.3	120	12.5	85
27	18.1	19.0	3,000	16.6	600	14.4	200	13.2	120	12.6	80
28	17.7	19.8	3,000	16.5	500	14.4	110	13.0	120	12.8	75
29	17.9	20.4	3,000	16.1	500	14.4	200	13.0	120	12.8	90
30	17.8	20.2	3,000	15.8	350	14.3	150	12.9	120	13.0	95
31	.....	20.1	3,000	15.6	250	.....	.....	13.0	150	.....	.....

[a] Silica standard; determinations made with U. S. Geol. Survey turbidity rod.

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COPPER RIVER AT MILES GLACIER.

Gage-height records were kept on Copper River by the Copper River & Northwestern Railway Co. from 1907 to 1910. The exact location of the gage is not known, but it was probably near the site of the bridge constructed during that period between Childs and Miles glaciers, 49 miles from Cordova and about 40 miles from the Pacific Ocean. (See Pl. V, *B*.) The datum plane of the gage was at an elevation equal to mean low-tide level at Cordova. To reduce the following gage heights that were taken at that point to their actual elevation above the datum plane, add 100 feet. Readings taken after about the 1st of November of each year may have been affected by ice, but no definite information is available regarding such conditions. No discharge measurements were made previous to 1913. It is not thought advisable to estimate discharges for 1907–1910 because of uncertainties regarding changes in channel since that period.

On June 29, 1913, a chain gage was installed by the Geological Survey on the railroad bridge on the guard timber on the upstream side of the center panel of the third span from the east bank. The gage datum was 85.3 feet below the base of the rails, or 93 feet above mean low-tide level at Cordova.

Discharge measurements were made from the upstream side of the bridge.

The channel at the bridge is composed of gravel and bowlders and is believed to be fairly permanent. The control for the section at the bridge is not well defined and the gage heights may have been affected at times by the action of ice breaking from the face of Childs Glacier, which would not only tend to contract the section and back up the water but also might change the condition of the bed of the river at the control.

Discharge measurements of Copper River at Miles Glacier in 1913.

Date.	Width.	Area of section.	Mean velocity	Gage height.	Discharge.	Date.	Width.	Area of section.	Mean velocity	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet per sec.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sq. ft.*	*Feet per sec.*	*Feet.*	*Sec.-ft.*
June 30	1,440	13,400	15.52	40.5	208,000	Nov. 12	990	6,250	2.78	[a] 27.6	17,400
Sept. 13	1,007	7,330	5.47	28.0	40,100						

[a] Backwater from ice on riffle below section.

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Daily gage height, in feet, of Copper River at Miles Glacier for 1907–1910.

[A. O. Johnson, observer. Records furnished by the Copper River & Northwestern Railway.]

Day.	Aug.	Sept.	Oct.	Nov.	Day.	Aug.	Sept.	Oct.	Nov.
1907.					1907.				
1	.....	24.0	20.8	16.4	16	28.0	22.7	20.0	18.4
2	.....	23.8	21.2	16.3	17	28.0	23.5	19.5	18.4
3	29.2	23.5	22.0	16.2	18	28.0	24.2	19.9	18.5
4	29.0	23.2	22.6	16.1	19	27.9	25.0	20.2	18.6
5	28.8	23.0	23.0	16.0	20	27.7	25.8	20.3	18.7
6	28.5	22.8	23.0	16.2	21	27.4	26.5	20.3	18.9
7	28.4	22.5	23.0	16.4	22	27.2	26.7	20.2	19.0
8	28.3	22.2	23.0	16.8	23	27.0	26.2	20.1	19.0
9	28.1	22.0	22.8	17.2	24	26.9	25.9	20.0	19.0
10	28.0	21.9	22.7	17.5	25	26.5	25.0	19.7	19.1
11	27.8	21.7	22.4	17.7	26	26.0	24.0	19.4	19.2
12	27.6	21.5	22.0	17.9	27	25.5	23.0	19.0	[a] 19.2
13	27.5	21.9	21.6	18.1	28	25.1	21.9	18.6	.....
14	27.5	22.1	21.0	18.3	29	24.8	21.0	17.9	.....
15	27.7	22.4	20.5	18.4	30	24.6	20.5	17.0	.....
					31	24.4	20.4	16.5	.....

[a] River frozen after Nov. 27.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908.								1908.							
1	[a] 23.0	31.7	28.2	25.9	19.0	18.8	18.3	16	25.7	28.8	27.7	22.0	18.4	19.0	18.2
2	22.8	31.5	28.5	26.0	19.4	19.7	18.4	17	25.8	29.0	27.0	23.9	18.4	19.0	18.5
3	23.1	31.0	27.8	26.4	19.7	20.1	18.3	18	26.0	29.7	26.5	23.8	18.6	19.0	18.6
4	23.2	30.5	27.3	26.7	19.9	20.2	18.4	19	26.5	29.2	26.7	23.4	18.6	19.3	18.7
5	23.1	29.9	27.2	26.8	19.5	20.3	18.4	20	28.0	29.0	26.9	23.0	18.6	19.4	18.7
6	23.0	29.1	27.0	25.8	19.3	20.4	18.4	21	28.7	28.9	26.8	22.0	18.5	19.3	18.7
7	23.0	28.6	27.0	25.0	19.0	20.5	18.4	22	29.4	28.4	26.5	21.4	18.0	19.1	18.6
8	23.0	28.0	27.3	23.6	19.0	20.5	18.4	23	30.0	28.0	26.0	20.9	17.4	19.0	18.6
9	23.0	27.5	28.0	23.0	19.0	20.3	18.3	24	30.7	27.5	26.0	20.7	17.1	18.9	18.7
10	23.2	27.5	28.5	22.5	19.0	20.2	18.5	25	31.6	27.2	26.0	20.2	17.0	18.8	18.8
11	23.8	28.3	28.0	22.2	19.0	20.0	18.5	26	32.0	27.0	25.8	19.8	17.5	18.7	18.8
12	24.0	30.2	28.2	22.0	19.0	19.6	18.3	27	31.4	26.8	25.8	19.4	17.8	18.8	18.9
13	24.4	31.0	28.6	21.6	19.0	19.5	18.3	28	31.0	26.8	25.8	19.2	18.0	18.5	18.8
14	24.7	30.0	28.3	21.3	18.8	19.2	18.4	29	30.7	27.0	25.8	19.2	18.2	18.3	18.6
15	25.0	29.1	28.0	21.3	18.6	19.0	18.2	30	31.2	27.4	25.5	19.3	18.4	18.3	18.5
								31	.....	28.0	25.5	.....	18.6	.....	18.5

[a] Ice in river broke up June 1.

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Daily gage height, in feet, of Copper River at Miles Glacier for 1907–1910—Continued.

Day.	Jan.	Feb.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1909.									
1	18.6	.....	.....	22.9	30.0	30.8	26.0	19.9	19.3
2	18.6	.....	.....	22.6	31.0	30.7	25.2	19.7	19.4
3	18.6	.....	.....	22.2	30.1	29.8	24.9	19.1	19.4
4	18.5	.....	.....	22.0	29.1	29.4	24.6	18.9	19.6
5	18.5	.....	22.0	22.0	29.0	29.7	24.7	18.5	19.7
6	18.5	.....	22.1	21.8	28.1	29.7	25.7	18.3	19.7
7	.....	.....	22.3	21.7	28.1	29.5	24.9	18.1	19.8
8	.....	20.5	22.9	22.3	28.0	29.3	24.7	18.1	19.8
9	.....	21.0	23.0	23.2	28.0	29.4	24.5	17.9	19.9
10	.....	28.5	23.2	22.5	29.0	29.5	24.1	17.7	19.9
11	.....	34.5	23.4	22.7	29.0	30.1	24.3	18.0	20.7
12	.....	37.3	23.2	22.7	29.0	31.2	24.0	23.8	20.7
13	.....	38.9	23.5	22.5	28.1	30.9	23.7	23.5	20.6
14	.....	40.0	23.7	22.3	29.0	30.4	23.5	21.9	20.6
15	.....	32.5	23.6	22.2	28.9	29.2	23.1	21.1	20.6
16	.....	23.5	23.6	22.4	29.0	28.3	23.1	20.8	20.5
17	.....	21.5	24.0	23.3	29.0	28.6	22.7	20.2	20.5
18	.....	20.6	24.5	23.3	29.6	28.0	22.5	19.7	.....
19	.....	20.1	24.0	23.5	30.2	27.9	22.7	19.7	.....
20	.....	20.1	23.7	23.0	30.2	28.6	23.4	19.7	.....
21	.....	.....	23.5	22.6	30.2	28.6	22.0	419.2	.....
22	.....	.....	23.0	22.4	30.3	28.4	21.4	18.9	.....
23	.....	.....	22.7	22.7	30.1	26.9	21.0	18.6	.....
24	.....	.....	22.0	23.5	30.3	27.1	20.9	19.1	.....
25	.....	.....	22.0	23.9	30.6	27.5	20.4	19.4	.....
26	.....	.....	22.0	24.5	30.9	27.8	20.2	19.6	.....
27	.....	.....	22.4	25.0	30.3	28.0	19.8	19.3	.....
28	.....	.....	22.7	26.6	31.5	27.9	19.7	19.2	.....
29	.....	.....	22.7	28.0	31.5	26.0	19.7	19.2	.....
30	.....	.....	22.8	29.6	31.6	26.2	20.0	19.2	.....
31	.....	.....	22.9	.....	31.5	26.3	.....	19.3	.....

NOTE.—River frozen over Jan. 6. Ice broke up Feb. 8, caused by lake in Miles Glacier breaking loose. River frozen over Feb. 20. River broke up May 5. River frozen over after Nov. 17.

[H. A. Brown, observer.]

Day.	May.	June.	Day.	May.	June.	Day.	May.	June.
1910.			**1910.**			**1910.**		
1	.....	24.5	11	.....	22.0	21	.....	24.4
2	.....	24.1	12	.....	21.8	22	.....	26.5
3	.....	24.2	13	.....	21.6	23	28.9	26.8
4	.....	24.1	14	.....	22.0	24	28.8	27.1
5	.....	23.3	15	.....	22.4	25	28.5	27.9
6	.....	23.3	16	.....	22.6	26	31.1	28.7
7	.....	22.8	17	.....	22.9	27	32.3	29.0
8	.....	22.5	18	.....	23.0	28	29.5	27.4
9	.....	22.4	19	.....	23.6	29	26.3	27.0
10	.....	22.2	20	.....	23.7	30	25.8	28.4
						31	25.5	.....

NOTE.—Ice broke up May 23. Gage heights during May affected by ice.

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Daily gage height, in feet, and discharge, in second-feet, of Copper River at Miles Glacier for 1913.

[Drainage area, 21,800 square miles. Andrew Beck, observer.]

Day.	June.		July.		August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			39.2	186,000	36.4	142,000			28.0	40,100		
2							31.2	70,400				
3			39.8	197,000								
4									26.0	27,500		
5												
6			38.7	179,000	33.9	106,000	29.2	50,000				
7									26.0	27,500		
8			39.9	198,000								
9							28.0	40,100				
10			38.6	178,000								
11					34.4	113,000						
12												17,400
13												
14												
15			39.5	192,000	32.2	82,600						
16			41.0	216,000	31.9	78,700						
17							28.5	44,000				
18												
19					31.2	70,400	28.4	43,200				
20			35.5	128,000								
21							28.9	47,200				
22			35.4	127,000								
23			34.7	117,000	33.4	98,600	34.5	114,000				
24												
25							36.2	139,000				
26			36.4	142,000								
27			37.0	152,000	38.4	174,000						
28												
29	40.3	205,000	38.6	178,000			33.9	106,000				
30	40.5	208,000										
31					32.4	82,600						

NOTE.—Discharge determined from a rating curve based on two discharge measurements; may be 15 per cent in error.

KLUTINA RIVER BASIN.

GENERAL FEATURES.

The Klutina River basin comprises an area of approximately 1,040 square miles, bounded on the north and west by the Tazlina River basin and on the east by that of the Tonsina. The area to the south drains into Port Valdez.

Klutina River rises in Klutina Glacier on the north slope of the Chugach Mountains, flows northeastward and joins Copper River at Copper Center. About 15 miles below its source it enters Klutina Lake, and thence to its mouth, a distance of about 25 miles, it passes first through a region of mountains 3,000 to 4,000 feet high and then through the Copper River Plateau, in which its valley is incised between steep gravel walls to a depth of 400 to 500 feet. (See Pl. VII, *A*.) In its lower course through the plateau, a distance of about 13 miles, it falls 400 feet.

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A KLUTINA RIVER NEAR COPPER CENTER, LOOKING UPSTREAM.

B. McCARTHY CREEK.

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Klutina Lake is about 22 miles long, 4 miles in maximum width, 51 square miles in area. Much of the water of the river is derived from glaciers, but the lake acts as a settling basin and at its mouth the river is comparatively clear for a glacial stream. It carries only the finer material and shows little evidence of its glacial origin. The lake also regulates the flow of the river (see fig. 3), preventing extremely high rates of run-off during the summer, when the glaciers and snowbanks in the mountains are melting rapidly, and sudden decrease in flow in the fall when the glaciers become less productive.

Klutina Glacier is a northern arm of Valdez Glacier. In 1898 the Klutina Valley was the route of travel for many gold seekers on their way to the interior of Alaska and the Klondike region. The trail started from Valdez and followed the Valdez Glacier to the summit of the range and then down the Klutina Glacier to Klutina River, whose valley it followed to Copper Center. The following year the military trail was built over Thompson Pass and the Klutina route abandoned.

The discharge of 1,050 feet on October 31, 1913, which was probably the minimum since the beginning of the open season in May would be sufficient to produce about 80 horsepower for each foot of fall with an efficiency of 70 per cent at the wheel.

KLUTINA RIVER AT COPPER CENTER.

A gaging station was established June 17, 1913, at the crossing of the Government wagon road, and gage readings were taken night and morning each day until October 31, when ice rendered gage readings valueless as an indication of the discharge. The river flows in two channels at the road crossing. A vertical staff gage was installed on a pier of each bridge. Readings from the gage in the left or main channel were used in estimating the entire flow, as that channel seemed to be more permanent than the right, which shifted considerably.

Discharge measurements of Klutina River at Copper Center, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
June 18	8.73	4,650	Sept. 26	7.50	2,070

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Daily gage height, in feet, of Klutina River at Copper Center for 1908.

[Chas. W. H. Heideman, observer.]

Day.	May.[a]	June.	July.	Aug.	Day.	May.[a]	June.	July.	Aug.
1	.....	3.8	5.5	4.5	16	.....	4.2	5.2	4.1
2	.....	4.2	5.5	4.5	17	.....	4.5	5.1	.....
3	.....	4.0	5.4	4.6	18	(a)	4.8	5.0	.....
4	.....	3.8	5.4	4.6	19	3.3	5.0	5.0	4.2
5	.....	4.2	5.3	4.6	20	4.3	5.1	5.0	4.1
6	.....	4.5	5.1	4.5	21	4.2	5.1	5.1	3.7
7	.....	4.8	5.1	4.5	22	3.3	5.2	5.0	3.5
8	.....	4.0	5.0	4.5	23	.....	5.3	5.0	3.0
9	.....	3.7	4.8	4.4	24	4.4	5.3	4.9	3.0
10	.....	4.1	4.6	4.4	25	3.8	5.4	4.8	3.0
11	.....	4.2	4.9	4.3	26	3.4	5.5	4.8	2.9
12	.....	4.3	5.0	4.2	27	3.0	5.5	4.8	2.9
13	.....	4.1	5.0	4.0	28	3.4	5.6	4.7	3.0
14	.....	4.0	5.1	4.0	29	3.3	5.5	4.6	2.9
15	.....	4.2	5.2	4.1	30	3.4	5.4	4.6	2.9
					31	3.6	.....	4.6	2.9

[a] Ice went out May 18.

NOTE.—Records furnished by Mr. Heideman, who was in charge of the Government experiment farm. Gage was on the middle pier of the bridge, about one-half mile from Copper River.

Daily gage height, in feet, and discharge, in second-feet, of Klutina River at Copper Center for 1913.

[Drainage area, 1,040 square miles. Chas. Morris, observer.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	9.4	7,300	8.5	3,960	8.15	3,160	7.5	2,070
2	.....	.....	9.35	7,060	8.5	3,960	8.0	2,860	7.5	2,070
3	.....	.....	9.35	7,060	8.4	3,720	7.95	2,770	7.45	2,010
4	.....	.....	9.3	6,820	8.4	3,720	7.8	2,510	7.4	1,950
5	.....	.....	9.3	6,820	8.4	3,720	7.75	2,430	7.4	1,950
6	.....	.....	9.3	6,820	8.4	3,720	7.65	2,280	7.3	1,830
7	.....	.....	9.3	6,820	8.4	3,720	7.6	2,200	7.2	1,720
8	.....	.....	9.4	7,300	8.4	3,720	7.5	2,070	7.2	1,720
9	.....	.....	9.4	7,300	8.35	3,600	7.4	1,950	7.05	1,580
10	.....	.....	9.3	6,820	8.4	3,720	7.3	1,830	6.9	1,440
11	.....	.....	9.3	6,820	8.4	3,720	7.3	1,830	6.8	1,350
12	.....	.....	9.3	6,820	8.45	3,840	7.25	1,780	6.8	1,350
13	.....	.....	9.3	6,820	8.45	3,840	7.2	1,720	6.75	1,310
14	.....	.....	9.3	6,820	8.4	3,720	7.1	1,620	6.7	1,270
15	.....	.....	9.3	6,820	8.4	3,720	7.1	1,620	6.6	1,200
16	.....	.....	9.25	6,600	8.3	3,490	7.05	1,580	6.55	1,170
17	8.75	4,660	9.2	6,370	8.2	3,270	7.0	1,530	6.55	1,170
18	8.75	4,660	9.15	6,160	8.15	3,160	6.95	1,480	6.5	1,140
19	8.8	4,820	9.05	5,750	8.1	3,060	6.95	1,480	6.5	1,140
20	8.85	5,000	9.0	5,550	8.1	3,060	6.9	1,440	6.5	1,140
21	8.85	5,000	8.95	5,360	8.1	3,060	6.85	1,400	6.5	1,140
22	8.85	5,000	8.9	5,170	8.1	3,060	6.8	1,350	6.5	1,140
23	8.9	5,170	8.85	5,000	8.1	3,060	7.1	1,620	6.5	1,140
24	8.9	5,170	8.8	4,820	8.2	3,270	7.3	1,830	6.5	1,140
25	9.0	5,550	8.8	4,820	8.25	3,380	7.35	1,890	6.5	1,140
26	9.1	5,950	8.8	4,820	8.3	3,490	7.5	2,070	6.5	1,140
27	9.3	6,820	8.8	4,820	8.3	3,490	7.5	2,070	6.5	1,140
28	9.35	7,060	8.8	4,820	8.35	3,600	7.55	2,140	6.5	1,140
29	9.4	7,300	8.7	4,510	8.3	3,490	7.55	2,140	6.45	1,110
30	9.4	7,300	8.55	4,090	8.3	3,490	7.55	2,140	6.4	1,080
31	.....	.....	8.5	3,960	8.25	3,380	.....	.....	6.35	1,050
Mean discharge		5,680		6,030		3,520		1,960		1,390
Second-feet per square mile		5.46		5.80		3.39		1.88		1.34
Run-off, depth in inches		2.84		6.69		3.91		2.10		1.54
Maximum		7,300		7,300		3,960		3,160		2,070
Minimum		4,660		3,960		3,060		1,350		1,050
Accuracy		C.		C.		C.		C.		D.

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KOTSINA RIVER BASIN.

Kotsina River heads in large glaciers on the southwestern slope of the Wrangell Mountains, between Kuskulana and Chesnina rivers. It follows a very irregular course with a general southeasterly trend, is about 40 miles long, and joins Copper River from the east just above the mouth of the Chitina. The basin covers an area of 447 square miles. Its topographic features, like those of most of the tributaries of the upper Copper River, are exceedingly diverse. The upper 20 miles of its valley lies between high rugged mountains. Its course below the mountain is through the southeastern corner of the Copper River Plateau, in which it has cut a deep canyon, in some places through hard rock, in others through gravel and conglomerate.

Through the summer the river carries a large volume of water with the usual amount of débris that would be expected of a stream whose source is mainly from glaciers. Peacock, Roaring, Rock, Copper, and Elliott creeks are the principal tributaries from the south and east. They are all without glacial source except one minor glacier near the head of Rock Creek. The Great Northern Development Co. has installed a hydroelectric plant of 17 kilowatts capacity on Roaring Creek for use in the development of copper properties. Roaring Creek drains an area of 10.1 square miles. There is said to be a good site for a small water-power plant on Peacock Creek. It drains an area of 6.3 square miles. From the topographic map Elliott Creek shows a fall of 1,000 feet in the lower 2 miles of its course. It is 8 miles long and drains an area of 16.9 square miles. From the north the tributaries of the Kotsina nearly all have glacial origin. Kluvesna Creek, one of the largest of the northern branches, heads in Kluvesna Glacier. Falls Creek, a tributary of the Kluvesna, has a heavy grade and is said to offer a good opportunity for the development of water power in the summer.

No daily records of flow in the Kotsina basin have been kept by the Survey.

A measurement was made near the mouth of the Kotsina, as follows:

November 9, 1913: Discharge, 200 second-feet; drainage area, 447 square miles; discharge per square mile, 0.45 second-foot.

CHITINA RIVER BASIN.

GENERAL FEATURES.

Chitina River, the largest tributary of Copper River, drains an area of 6,260 square miles. It rises in the St. Elias Range near the international boundary and flows northwestward for more than 100 miles to the Copper. It occupies a broad valley of gravel deposits, through which it has cut a deep trench in the lower 50 or 60 miles of its course.

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Near the mouth of the Nizina the valley attains a width of nearly 15 miles. Below that point the valley is somewhat narrower and is broken by many small isolated peaks and rolling hills.

Much of the valley is imperfectly drained, and depressions resulting from glacial action are filled with water, forming many lakes and ponds and considerable areas of swamp land. The flood plain of the river is a mile or more in width at many places and shows all the characteristics of a plain formed by glacial stream.

The most important tributaries of the Chitina are from the north and emanate principally from the south slope of the Wrangell Mountains; in order downstream they are Nizina, Lakina, Gilahina, and Kuskulana rivers. From the south the main affluents are the Tana, Chakina, and Tebay rivers, which rise in the Chugach Mountains.

Tana River heads in Tana Glacier, a long westward arm of the massive ice sheet that surrounds Mount St. Elias and that eastward drains into the Alsek River in Yukon Territory. Tebay River, which joins the Chitina about 20 miles above the Copper, drains the Hanagita Valley and receives through its more southerly branches the discharge from a few minor glaciers. Between the Hanagita Valley and the Chitina, a distance of about 6 miles, the Tebay falls over 1,000 feet. There are several lakes in the headwaters which might possibly be made to afford considerable storage.

The flow of the streams during the summer depends largely on the melting of the glaciers, and in so far as that factor prevails the variations bear a direct relation to the temperature. The precipitation at the lower levels is rather low, probably not exceeding 18 inches per year, with only a moderate snowfall. At the higher levels the precipitation is believed to be much greater. Deep snow banks remaining late into the summer help keep up the flow on many of the streams. Summer rains can not be depended on, but they occasionally cause high water and, when accompanied by warm winds, are likely to cause excessive floods. The winter flow depends almost entirely on underground sources. Many of the smaller streams are said to go dry for several months, whereas others draining much smaller basins maintain a considerable flow throughout the winter, the difference being due to the character of the underlying formations on which the circulation of water and its escape to the surface depend. The geology of the northern portion of the Chitina basin is outlined by Moffit and Maddren [1] as follows:

Both sedimentary and igneous rocks are encountered. Four principal formations, including the unnamed Triassic shales and limestones, occupy most of the area and appear throughout its length from east to west. These formations, in order from oldest to youngest, are the Nikolai greenstone, the Chitistone limestone, the Triassic

[1] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, p. 21, 1909.

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limestones and shales, and the Kennicott formation. The rocks have been folded and faulted, but the metamorphism is not great. It is most noticeable in the greenstone but has hardly affected the Kennicott formation.

The limestone, because of its solubility, should offer favorable conditions for underground storage, and the folded and faulted condition of the greenstones and shales is also favorable for underground storage and circulation of deep-seated waters. The foregoing statements are at best only general and should not be construed to mean that a large winter run-off would be the rule. Any statement of stream-flow conditions in this northern latitude is hardly worth considering unless based on actual observation.

NIZINA RIVER BASIN.

GENERAL FEATURES.

Nizina River, the largest branch of the Chitina, heads in Nizina Glacier, flows southward about 16 miles to a point near the mouth of Dan Creek, where it takes an easterly course, which it follows for about 22 miles to its union with the Chitina. It drains an area of 1,240 square miles and is nearly as large as the Chitina at their junction.

For the first 20 miles of its course it flows over a gravel flood plain from one-half to 2 miles wide, bordered by steep-sloped mountains 6,000 to 8,000 feet in height. At low water it follows one or more constantly shifting channels. At medium stage the number of channels increases, and finally at flood height the entire flood plain becomes covered from bank to bank with swift-flowing, muddy water carrying large quantities of sand and gravel. Below Young Creek the bordering mountains are separated by a wider valley in which the river has cut a deep trench through the gravel and shale formations; finally, for the last 2 or 3 miles of its course, the river flows between walls of solid rock, forming a box canyon for much of the distance. Small boats have been taken down through the canyon but always with considerable danger. The river has an average grade of about 30 feet per mile. Several thousand horsepower could be developed during the summer months by constructing a dam at the canyon, but probably the difficulties and expense of passing the immense quantities of sand and gravel that would be brought down against a dam would be so great as to render such a project impracticable.

Chitistone River rises in Russell Glacier near Skolai Pass, about 25 miles northeast from its confluence with the Nizina. Its course lies in a narrow valley with steep-sloped mountains 8,000 to 9,000 feet high on either side. It is reported that in some sections it passes through narrow, rock-walled canyons for short distances.

Dan and Chititu creeks are small streams that enter the Nizina from the southeast about 6 miles and 8 miles, respectively, below Chitistone

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River. They flow past important gold placer claims, and their waters are particularly valuable for hydraulic mining. The basin of Dan Creek comprises 42 square miles and that of Chititu Creek 27 square miles.

Young Creek, which enters the Nizina about 1 mile below Chititu Creek, is about 30 miles long and drains an area of 104 square miles. Its lower course parallels that of Chititu Creek, about which its headwaters turn, interlocking with those of Dan Creek. Neither Dan, Chititu, nor Young creek receives much, if any, glacial water. They carry large quantities of silt from the shale formation in which they have cut their channels, besides much gravel and sand from the overlying formation.

Kennicott River carries the flow from Kennicott Glacier to the Nizina River, a distance of about 4 miles. It is subject to extreme floods, usually one or more each year, which are caused by the clogging of the subglacial channels that open up with an immense flow after enough water has accumulated to produce sufficient pressure to force out the obstruction. The flood discharge sometimes lasts several days.

McCarthy Creek (Pl. VII, *B*, p. 50) rises in small glaciers on the south slope of the Wrangell Mountains and for about 13 miles flows southward, paralleling Kennicott Glacier, which lies 3 to 4 miles to the west. The dividing ridge is a southern spur from the Wrangell Mountains and ranges from 6,000 to 7,000 feet in height. McCarthy Creek then gradually bends toward the west, and for the last 3 miles flows about northwest. Its total length is about 20 miles, and it enters Kennicott River at the town of McCarthy. The basin comprises 72 square miles. The principal tributaries are from the east and are the East Fork and Nikolai Creek, which enter about 10 miles and 12 miles, respectively, below the head. Below the East Fork the stream flows between high gravel banks, meeting here and there ledges of shale and porphyry through which it has cut its way, forming small canyons. About 3 miles from its mouth, as it enters the valley of the Kennicott, the flood plain broadens and averages nearly one-fourth of a mile in width. McCarthy Creek has a rather uniform grade of about 100 feet per mile. Considerable power could be developed from about the middle of May until the middle of October; for the remainder of the year extreme cold greatly reduces the flow (see fig. 3) and causes excessive formation of ice. Water could be diverted to a flume or pressure pipe and carried down the valley until a sufficient head could be obtained. A pressure pipe would probably be cheaper in the long run than a flume. A pipe line could be cheaply laid along the valley bottom without much danger from high water. The valley slopes are composed largely of steep gravel banks that would offer rather unstable support for a flume. The only engineering

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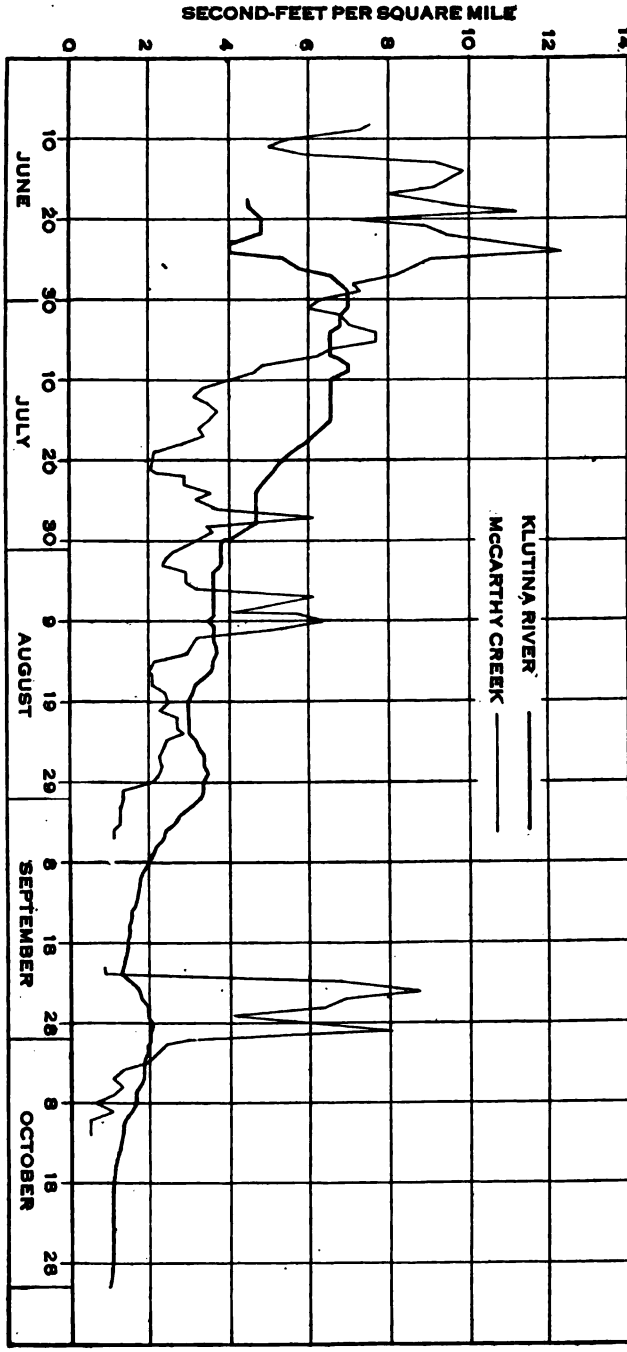

FIGURE 3.—Diagram showing discharge, in second-feet per square mile, of Klutina River and McCarthy Creek, for 1913.

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difficulty that would be encountered would be the designing of headworks that would effectively divert the water into a flume or pipe line and at the same time withstand the effect of flood pressures and prevent the entrance of sand and gravel into the conduit. On October 12, 1913, there was a discharge of 37 second-feet, which it is probably safe to assume was the minimum flow since the beginning of the open season in May. That amount of water would produce nearly 300 horsepower for every hundred feet of fall, with an efficiency of 70 per cent at the wheel.

Miscellaneous measurements were made at several points in the Nizina River basin in 1913, and a regular gaging station was established on McCarthy Creek near its mouth.

McCARTHY CREEK NEAR McCARTHY.

This station was established June 8, 1913. The gage is a vertical staff on the right bank of the creek about three-quarters of a mile above the mouth.

Measurements were made from a car and cable at high water and by wading at low and medium stages.

The bed of the stream is composed of sand, gravel, and bowlders. The control at the gage did not change appreciably during 1913 and is believed to be fairly permanent except during flood stages, when radical changes might take place.

This station was established and records were obtained in cooperation with the Kennicott Mines Co.

Discharge measurements of McCarthy Creek near McCarthy in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 29	3.85	191	Nov. 3	3.00	37
June 8	4.63	540	5	3.50	[a] 24
Sept. 21	3.29	61			

[a] Backwater caused by anchor ice.

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Daily gage height, in feet, and discharge, in second-feet, of McCarthy Creek near McCarthy for 1913.

[Drainage area, 71 square miles. A. V. Dose, observer.]

Day.	June.		July.		August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			4.40	427	3.80	170	3.49	91	3.80	170		
2			4.52	485	3.81	174	3.48	90		154		
3			4.54	495	3.90	210	3.49	91	3.70	139	3.00	37
4			4.64	544	3.90	210	3.45	84	3.50	93		
5			4.64	544	3.94	226	3.44	83	3.40	76		24
6			4.48	465	4.42	437			3.49	91		
7			4.42	437	4.26	362			3.40	76		
8	4.63	539	4.22	344	4.38	418			3.10	44		
9	4.59	519	4.18	326	4.45	451			3.40	76		
10	4.32	389	4.08	282	4.30	380			3.00	37		
11	4.24	353	4.00	250	3.94	226				37		
12	4.38	418	3.92	218	3.92	218			3.00	37		
13	4.86	654	3.98	242	3.90	210						
14	4.95	700	4.04	266	3.75	154						
15	4.92	684	4.01	254	3.72	145						
16	4.86	654	3.95	230	3.74	151						
17	4.68	564	3.97	238	3.74	151						
18	4.88	664	3.88	202	3.80	170						
19	5.14	798	3.74	151	3.81	174						
20	4.56	504	3.68	134	3.76	158						
21	4.82	634	3.72	145	3.84	186	3.29	61				
22	4.89	669	3.89	206	3.84	186	3.31	63				
23	5.10	777	3.89	206	3.88	202	4.51	480				
24	5.29	876	4.00	250	3.80	170	4.80	624				
25	4.84	644	3.94	226	3.79	167	4.52	485				
26	4.77	609	4.02	258	3.76	158	4.45	451				
27	4.70	574	4.42	437	3.77	161	4.10	290				
28	4.56	504	3.98	242	3.76	158						
29	4.59	519	3.99	246	3.74	151	4.70	574				
30	4.44	446	3.94	226	3.52	97	3.90	210				
31			3.84	186	3.52	97						
Mean discharge		595		296		211				85.8		
Second-feet per square mile		8.38		4.17		2.97				1.21		
Run-off, depth in inches		7.17		4.81		3.42				.54		
Maximum		876		544		451				170		
Minimum		353		134		97				37		
Accuracy		A.		A.		A.				A.		

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MISCELLANEOUS MEASUREMENTS.

The following table shows the results of miscellaneous discharge measurements made in the Nizina River basin in 1913:

Miscellaneous measurements in Nizina River drainage basin in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. m.*	*Sec.-ft.*
Nov. 4	Nizina River	Chitina River	5 miles above Kennicott River.	492	865	0.45
May 31	Dan Creek	Nizina River	Above hydraulic plant	37	40	.92
June 1	White Creek	Chititu Creek	Above Jolly Gulch	14.1	9.4	1.50
3	Chititu Creek	Nizina River	Below junction White and Rex creeks.	53	24	2.21
3	Rex Creek	Chititu Creek	Above hydraulic plant	18.4	9.5	1.94
Nov. 5	McCarthy Creek	Kennicott River	Above Nikolai Creek	21	48	.44

LAKINA RIVER BASIN.

GENERAL FEATURES.

Lakina River, the first important tributary of Chitina River below the Nizina, rises in small glaciers between Kennicott Glacier on the east, Kuskulana Glacier on the north, and Gilahina River on the west. Castle Peak (elevation 10,514) is the highest point in the basin. The topography of the headwaters is rugged, but the basin does not extend as far north as the axis of the Wrangell Range. The river carries less glacial débris than the Nizina or the Kuskulana. The summer flow is probably derived to a considerable extent from melting snow in the higher peaks and depends on glacial flow to a less extent than any of the northern tributaries of the Chitina except the Gilahina.

One of the best stands of spruce in the Chitina basin is found along the banks of the Lakina as it leaves the mountains and starts across the Chitina Valley. The trees are not large, probably but few are over 18 inches in diameter, but they are said to be of fair quality. A small portable sawmill was in operation near the railroad crossing during the summer of 1913. The lumber was used largely for building at McCarthy. At the present rate of consumption the supply large enough for saw logs will become exhausted in a few seasons.

The Lakina is about 28 miles long, and its average grade is 70 feet per mile. There are no natural dam sites or storage sites so far as known on the river, but considerable power could be developed for about six months in the year by carrying the water along the side of the valley, either in an open conduit or a pipe, until sufficient head was obtained. On October 31, 1913, there was a discharge of 99 second-feet at the railroad crossing, which was probably the minimum flow since the beginning of the open season in May. That

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amount of water would produce 787 horsepower per 100 feet of fall with an efficiency of 70 per cent at the wheel. The relatively small amount of sediment carried by the river makes it more desirable for power development than many streams that in other respects are superior.

A gage was installed on the creek near the railroad crossing on June 9, 1913, but no daily readings were obtained.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in the Lakina River basin are shown in the following table:

Miscellaneous measurements in Lakina River drainage basin in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
			Feet.	*Sec.-ft.*	*Sq. miles.*	*Sec.-ft.*
June 9	Lakina River	Railroad crossing	4.09	[a] 1,750	124	14.11
Oct. 3	do	do	2.24	224	124	1.81
31	do	do	[b] 2.50	99	124	.80

[a] Float measurement. [b] Gage height affected by ice.

GILAHINA RIVER BASIN.

GENERAL FEATURES.

Gilahina River rises in mountains 6,000 to 7,000 feet high between Lakina River on the east and Kuskulana River on the west. It is about 12 miles long and joins the Chitina 9 miles below the Lakina. Three miles from the Chitina it forks. The west branch, which is called the Chokosna, drains an area of 50 square miles and is nearly as large as the main stream above the forks. The upper 6 miles of the Gilahina in its course through the mountains has a grade of about 150 feet per mile. As it approaches the Chitina Valley the grade increases, and for the lower 6 miles the average grade is about 200 feet per mile.

There are no glaciers in the basin, and at normal stages the water is clear and free from sediment. The valley floor is made up of gravel, bowlders, sand, and clay, and at high stages the stream transports considerable material, causing marked changes in the channel.

Gages were installed on the Gilahina and the Chokosna near the railroad crossing on June 10, 1913, and frequent readings were taken during the summer by employees of the Copper River & Northwestern Railway, but because of insufficient discharge measurements and various uncertainties regarding the readings it is not thought desirable to estimate daily discharges.

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MISCELLANEOUS MEASUREMENTS.

The results of discharge measurements made in the Gilahina basin are shown in the following table:

Miscellaneous measurements in Gilahina River drainage basin in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
			Feet.	*Sec.-ft.*	*Sq. mi.*	*Sec.-ft.*
June 10	Gilahina River	Railroad crossing	5.08	212	56	3.79
Oct. 2	do	do	4.54	81	56	1.45
June 10	Chokosna River	do	3.25	241	43	5.62
11	do	do	3.06	172	43	4.00
Oct. 1	do	do	2.58	69	43	1.60

KUSKULANA RIVER BASIN.

GENERAL FEATURES.

Kuskulana River has its source in Kuskulana Glacier at an elevation of about 2,200 feet. It flows southwestward for about 21 miles and joins Chitina River about 10 miles above the Copper at an elevation of approximately 600 feet, thus having an average grade of a little over 75 feet per mile. The main body of Kuskulana Glacier is about 11 miles long and slopes from east to west with an average width of about one-third mile. It receives four northern branches that emanate from the south and west slopes of Mount Blackburn. The basin above the Chitina Valley is exceedingly rugged. The snowfall in the higher mountains is said to be heavy, accumulating in massive drifts in the gulches and sheltered spots and in some places lasting throughout the summer. The river derives its main supply from Kuskulana Glacier and is heavily laden with glacial silt and sand.

In the upper 10 miles of its course the river passes through a broad gravel-filled flat, with high mountains on either side; its lower course of 11 miles across the Chitina Valley lies for much of the way through a steep rock-walled canyon. At the railroad crossing the rails are about 220 feet above the water surface, and the canyon within rock walls is about 170 feet deep. The width at the water surface, about 200 feet below the bridge, measured 70 feet, and the width at the top was estimated to be about 150 feet. The canyon affords many excellent dam sites. Below Strelna Creek it is in many places particularly narrow and its walls are nearly vertical. The river is said to get very low in the winter and goes dry at places in the upper basin above the canyon, where the underlying formation is composed of loose material. There is no opportunity for large storage in the basin, but the river offers opportunity for the development of a thousand horsepower or more for five or six months during the year by the construction of a dam at the canyon; but the winter flow is undoubtedly

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too low to warrant the operation of such a plant, even though ice difficulties could be overcome.

Extensive copper prospects in the upper basin indicate a possible future need of considerable power. The tributary streams above the canyon are all small. Nugget Creek, which is the largest, enters the main stream from the west just below the glacier. It drains an area of 12.1 square miles and falls about 800 feet in the lower 2 miles. Several other minor streams in the upper basin have heavy grades, and during warm weather, when their flow would be maintained by melting snow, they would probably produce sufficient power for small mining operations. An examination in the winter might show sufficient flow for small power plants on some of the side streams fed by springs with sufficient thermal properties to prevent the excessive formation of ice.

Strelna Creek, the most important tributary of the Kuskulana, heads in the ridge south of the Kotsina River, at an elevation of 6,000 to 7,000 feet, and enters the Kuskulana between 4 and 5 miles from the Chitina. It is about 12 miles long. The lower 6 miles of its course lie across the Chitina Valley plateau, with a grade of about 200 feet per mile. There are no glaciers in its basin, and the summer flow depends on rainfall and melting snow in the headwaters. Some winters it is said to go dry; in others there is a small flow even during the coldest weather.

No record of daily flow has been obtained in the Kuskulana basin. A gage was installed on the Kuskulana below the railroad bridge May 24, 1913, and was read every few days until about the middle of June, when the gage was washed out by high water; but an extremely shifting channel and insufficient measurements to determine the nature of such changes make it undesirable to attempt to estimate discharges from gage heights. A gage was also installed on Strelna Creek, at Strelna, on May 26, 1913, and a few gage readings were made, but the channel shifted so badly that without frequent measurements of discharge the gage heights would give little indication of the flow.

MISCELLANEOUS MEASUREMENTS.

The measurements that were made in the Kuskulana basin in 1913 are shown in the following table:

Miscellaneous measurements in Kuskulana River drainage basin in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
			Feet.	*Sec.-ft.*	*Sq. mi.*	*Sec.-ft.*
May 23	Kuskulana River	Railroad crossing	0.99	145	221	0.66
June 11	do	do	2.04	603	221	2.73
Oct. 1	do	do		[a] 500	221	2.26
Nov. 7	do	do		130	221	.59
June 11	Strelna Creek	do	3.05	46	25	1.84
27	do	do	3.40	55	25	2.20
Sept. 30	do	do	2.83	24	25	.96
Nov. 6	do	do	[b] 3.10	3.3	25	.13

[a] Estimated. [b] Backwater from heavy accumulation of anchor ice.

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TIEKEL RIVER BASIN.

GENERAL FEATURES.

Tiekel River is formed by the union of the Tsina River from the southwest and Kanata River from the north. It flows eastward about 15 miles and joins Copper River at mile 101 on the Copper River & Northwestern Railway, about 70 miles from the ocean. (See Pl. IV, *B*, p. 37.) Its course lies in a narrow valley bounded by high mountains on either side. The basin comprises an area of about 400 square miles, lying in the heart of the Chugach Range.

Between the forks and Copper River the Tiekel falls about 750 feet—an average of 50 feet per mile. About midway in its course through the mountains there is reported to be a cataract variously estimated at 20 to 50 feet in height, and narrow box canyons furnishing natural dam sites are also reported. It is not likely that any good storage sites exist, and the steep rock bluffs that flank the river bottom on each side would not offer favorable opportunity for the construction of a conduit.

During the summer the run-off is exceedingly heavy (see p. 66), and for at least five or six months the minimum flow would probably be sufficient to produce from 50 to 100 horsepower per foot of fall, but for several months during the winter the flow is doubtless very small, and without storage it would probably not be practicable to attempt to operate throughout the winter. Prediction of the effect of the formation of ice is difficult. The distance of the stream from the coast indicates that protracted periods of relatively cold weather should be expected.

There is but little timber in the main Tiekel River valley of size suitable for saw logs. Along the river banks and up to an elevation of about 2,000 feet, where it is not too rocky and steep, a dense growth of willows and alders is everywhere present. There are also a few scattered birch and spruce, but all are rather stunted. Just below the mouth of the Tiekel, along Copper River, there are a few large cottonwoods. Above Ptarmigan Drop the Tsina basin is barren of all timber except small brush. Below Ptarmigan Drop there are small clumps of spruce and cottonwood which have answered the local needs for fuel and cabin logs, but they are too small for saw logs. The Kanata River valley is somewhat better supplied with timber but would soon become exhausted if it was called upon to furnish logs for milling or fuel for power development.

Tsina River rises in glaciers lying in an unmapped area to the east of Valdez Glacier, from which they are probably eastward extensions. It is a typical glacial stream, flowing for the first 6 to 8 miles of its course in many constantly changing channels, which finally merge into one. (See Pl. VIII, *B*.) About 2 miles below Ptarmigan Drop

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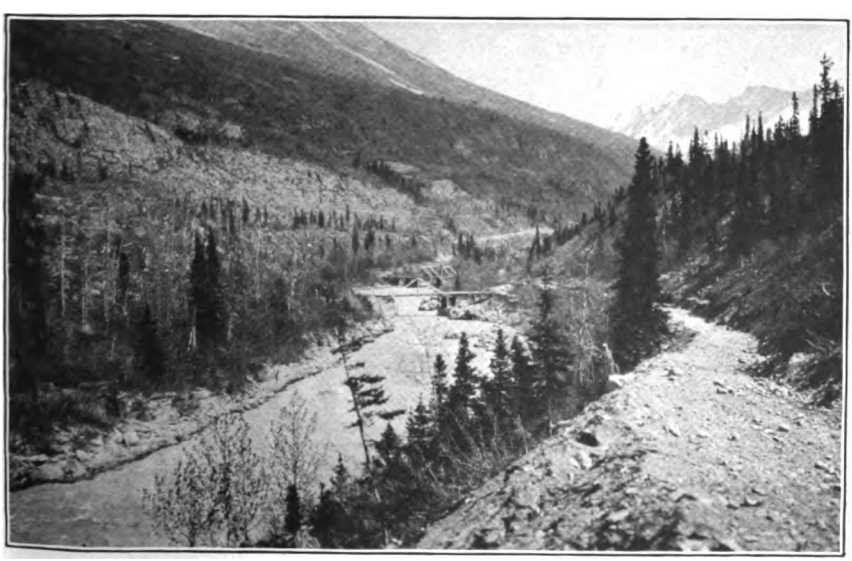
A. CANYON ON TSINA RIVER ABOUT 3½ MILES ABOVE BEAVER DAM ROAD HOUSE.



B. VIEW UP TSINA RIVER 4½ MILES ABOVE BEAVER DAM ROAD HOUSE.

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A. VIEW UP POWER CREEK FROM HEAD OF FALLS.

Snowslide across creek in the foreground.

B. POWER CREEK BASIN FROM EYAK LAKE.

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road house the valley narrows, and much of the way for the next 6 miles the river flows between rock walls that in some places rise 100 feet or more above the river bottom. The canyon affords several excellent dam sites. At a point about 3.5 miles above Beaver Dam road house the canyon is more than 100 feet deep. (See Pl. VIII, *A*.) The width was estimated to be 20 feet at the bottom and 100 feet at the top. The river has an average grade of about 50 feet per mile. It carries immense quantities of glacial débris during warm weather, but after about the 1st of September the water becomes clearer during normal flow. Tsina River, like many other glacial streams, is subject to extreme floods caused by the release of water that has been stored in the glaciers. On October 16, 1913, the river was discharging at least 1,500 second-feet, but two days later, without appreciable change in the weather, the flow had decreased to 87 second-feet. People living along the stream stated that the river commenced to rise rapidly on October 14.

About 1 mile above the Beaver Dam road house the valley suddenly broadens and the flood plain reaches a maximum width of a half mile or more. Passing through this enlarged section a distance of 3 or 4 miles, the river again enters a narrow valley in which it has cut a rock-walled canyon much of the way for 2 or 3 miles. On leaving the canyon it enters a big basin in which Kanata Creek enters from the north and the main Tiekel breaks through to the east. Stewart Creek joins the Tsina from the west less than a mile from the Tiekel. Kanata Creek is a clear-water stream and is about 15 miles long. It heads in a low divide near Ernestine road house.

Ptarmigan Creek, the largest southern tributary of the Tsina, heads in Thompson Pass (elevation about 2,690 feet) 18 miles east of Valdez. The basin occupies an area of about 18 square miles. The valley is broadly U-shaped, trends northeasterly, and is flanked by mountains 5,000 to 6,000 feet in elevation. The basin is narrow and precipitous on the east. To the west it is much wider and rises more gradually, and it is from this side that the greater part of the stream flow is derived. There are two glaciers on the west. Worthington Glacier, the northernmost and much the larger, extends well down toward the valley bottom and lies between the upper and lower canyons. On the east side of the basin several small glaciers lie high among the mountain peaks. The Government wagon road follows the west side of the creek until near the head of the lower canyon, where it crosses and soon enters the Tsina River valley. The creek is about 6 miles long and falls about 1,000 feet. About 500 feet of the fall is concentrated in two rock canyons. The upper canyon begins about 2 miles below Thompson Pass. A fall of about 200 feet occurs in a distance of approximately one-half mile. The lower canyon is

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near the mouth of the creek and through it the stream falls nearly 300 feet in a horizontal distance of about 1½ miles. Water could be easily diverted at the head of the upper or lower canyon and carried cheaply along either slope in a conduit of pipe or a combination of pipe and flume. With an efficiency of 70 per cent at the wheel about 16 and 24 horsepower could be developed at the upper and lower canyons, respectively, for each second-foot of discharge.

Ptarmigan Creek basin is barren of all trees except willows and alders, and if any of the several gold prospects that are now being developed in the basin should become mines, these water powers would become particularly valuable because of the absence of fuel. Water would probably not be available for the development of power before the last part of May, and by late November the diminished flow and heavy formation of ice would likely prohibit the operation of a plant until the following season.

MISCELLANEOUS MEASUREMENTS.

No daily records of stream flow have been kept in the Tiekel Basin, but miscellaneous measurements were made during 1913 and are listed in the following table:

Miscellaneous measurements in Tiekel River drainage basin in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. mi.*	*Sec.-ft.*
Oct. 20	Tsina River	Tiekel River	Below Ptarmigan Creek	87		
Nov. 9	do	do	do	50		
10	do	do	Mouth	134	161	0.83
June 13	Tiekel River	Copper River	do	5,820	408	14.3
July 1	do	do	do	8,480	408	20.8
Sept. 10	do	do	do	819	408	2.01
Oct. 17	Ptarmigan Creek	Tsina River	Below lake at head of upper canyon.	11.9	7.7	1.55
Nov. 8	do	do	do	2.8	7.7	.36
Oct. 18	do	do	2 miles above mouth at head of lower canyon.	22	16	1.38
Nov. 11	do	do	do	23	16	1.44
Oct. 19	Stuart Creek	do	At mouth	14.8		
Nov. 10	do	do	do	8.0		
Oct. 19	Kanata River	Tiekel River	do	146	175	.83
Nov. 10	do	do	do	69	175	.39

WATER-POWER SITES.

The topography of the Copper River basin is in many respects favorable for water-power development. The Wrangell and Chugach mountains give a heavy grade and many waterfalls to the streams emanating from them and contribute a heavy summer flow derived from the melting of glaciers and of snow banks accumulated during the previous winter. Natural storage sites in the form of lakes and ponds or opportunities for the creation of large storage basins by

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dams, features second only in importance to the discharge and grade of the streams, are, however, not particularly favorable.

In the winter the run-off becomes very low, and it is doubtful if the development of water power will be found practicable during that season north of the Chugach Range. Without more data it is difficult to make even an approximate statement regarding the period during which the flow of the streams and the temperature conditions would permit the operation of a plant in that region, but from the best information available it appears that the extreme limits of time for the successful operation of such plants would be from about the 1st of May until the 1st of December. The same limits of operating time would also probably apply to the tributaries of the lower Copper unless considerable storage could be obtained.

The most natural sites for power development on the main Copper River are at Wood Canyon, about 6 miles below the Chitina, and at Abercrombie Rapids, about 10 miles above the delta. (See pp. 41–42.) A head of 40 to 50 feet could probably be obtained at each locality, thus affording opportunity for producing between 4,500 and 5,700 theoretical horsepower for each thousand second-feet of flow. The lowest flow measured in 1913 at the gaging station at Miles Glacier bridge was 17,400 second-feet on November 12. That probably represented the minimum flow since about the middle of May of that year. The discharge at Wood Canyon on the above date was probably about 15,000 second-feet, since the drainage area is about 15 per cent less than at the measuring section. The only inflow of consequence between Abercrombie Rapids and the measuring section is that from Miles Glacier. Both sites would be expensive to develop, and silt and ice would introduce serious operating problems. At the latter site the river is flanked on the east side by a moraine which might render the construction of stable headworks particularly difficult.

Numerous power sites of smaller capacity occur on the Nizina River, McCarthy Creek, Lakina, Kuskulana, and Tebay rivers, and many other tributaries of the Chitina. The Kotsina and other branches of the Copper that head in the Wrangell Mountains also afford favorable opportunities for power development. Of the lower Copper River tributaries the Tiekel is perhaps the principal power stream. There are also many smaller branches that flow from the Chugach Mountains on which considerable power could be developed. Such data as are available regarding these sites are included in the descriptions of the basins in which they occur.

In the mountainous regions the transmission of electricity would be very difficult and expensive because of the heavy snowfall and steep rocky slopes. High winds prevail in the lower Copper River

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valley (see table, pp. 31–32) and through many of the tributary valleys in that section during much of the winter.

Most of the tributaries of the Copper head in glaciers and carry large quantities of sand and silt during the summer.

At the present time, with coal costing $10 or more per ton at the coast and crude oil at $2 per barrel, hydroelectric power would probably be much cheaper than steam, even though the plant could be operated but six or seven months a year (see pp. 153–155), but in view of the many difficulties in the way of water-power development, such as short season and consequent necessity for auxiliary steam power, great variation in stream flow, transmission costs, and silt and ice conditions, it does not seem probable that large water-power plants will have much advantage over steam plants if fuel costs are reduced to as reasonable a figure as should be expected when the Bering River coal fields are opened up. In inaccessible regions where transportation costs would make fuel unduly expensive the small water powers will no doubt be of considerable value if energy is there needed for mining or other purposes.

McKINLEY LAKE DISTRICT.

The McKinley Lake district is important because of the occurrence of gold quartz veins,[1] although no mines have as yet been developed.

McKinley Lake lies west of the Copper River delta, about 20 miles east from Cordova and about 2 miles north of the railroad at Alaganik. It is about 1½ miles long and drains into Alaganik Slough. The surface of the lake is but little above mean tide level.

Salmon Creek is the largest stream in the district. It rises in several small glaciers in high rugged mountains south of Sherman Glacier and flows in a southerly direction for about 5 miles. Its valley lies north and east of McKinley Lake, from which it is separated by a low narrow ridge, which disappears gradually as the south end of the lake is approached. Salmon Creek waters are said to flood their banks at high stages and mingle with those of the lake near its southern end. At low stages the river is said to enter Alaganik Slough by a channel entirely independent of that from the lake. About 1 mile below its source the creek forks; the main stream leaves its glacier at an elevation of about 675 feet; the minor branch enters at an elevation of about 350 feet, and on July 26, 1913, its discharge was estimated to be nearly as much as the main branch. For about 1½ miles below the forks the gradient is about 125 feet per mile. In that section the stream is confined to a flood plain averaging roughly from 400 to 500 feet in width, with a floor of glacial débris through

[1] See Chapin, Theodore, The McKinley Lake district: U. S. Geol. Survey Bull. 542, pp. 78–80, 1912.

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which the stream meanders from bank to bank, usually confined to one channel at low and medium stages. The conditions along the valley show evidence of the movement of immense quantities of sand and gravel during flood stages.

A float measurement was made just below the fork (No. 1, Pl. X, p. 72) on July 26, 1913, at what appeared to be about a normal stage for that time of the year. A discharge of 119 second-feet was obtained. Considerable power could be developed during warm weather by diverting the water at the forks and carrying it in a conduit along the side of the valley for about 1½ miles, where a head of 150 to 200 feet could be obtained. From 10 to 15 horsepower could thus be produced for each second-foot of discharge. There is said to be a considerable flow throughout the winter, but it is not believed that it would be sufficient to warrant the operation of a plant for several months during the coldest weather. There are no sites along the creek where storage reservoirs could be provided.

The district is favored with an excellent stand of timber that would furnish cheap fuel for the development of steam power, and it seems likely that it would successfully compete with hydroelectric power, considering the rather unfavorable conditions for the development of the latter. The nearness of the railroad would permit the transportation of coal to the mines at a low cost.

POWER CREEK DRAINAGE BASIN.

GENERAL FEATURES.

Power Creek rises in Shepherd Glacier east of Orca Inlet and flows southwestward for about 5 miles, entering a northern arm of Eyak Lake about 4 miles northeast of the town of Cordova (Pl. IX, *B*, p. 65).

Eyak Lake is an irregular-shaped body of water lying east of Cordova. It is separated from Orca Inlet at Cordova by narrow lowlands, rising only a few feet above high-tide level and connecting a southern spur of Chugach Mountains with a small isolated range, to the south 3,000 to 4,000 feet high. The greatest dimension of the lake is from Cordova on the west to its outlet on the east, a distance of 4 or 5 miles. Its average width in a north-and-south direction is about 1 mile. It drains south through Eyak River to the Pacific Ocean, a distance of 5 or 6 miles across tidal swamps which border the coast and extend eastward to the Copper River delta. The level of the lake is raised a few inches by high tide backing up Eyak River. The Copper River & Northwestern Railway follows along the south shore of the lake.

Power Creek is bordered on both sides by high rugged mountains. The first 2 or 3 miles of its course is through a U-shaped glacial valley whose average width is about one-fourth mile. (See Pl. IX, *A*.)

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Extending across the lower end of the valley is a ridge 300 to 400 feet high, through which the creek has cut a narrow gorge at its eastern end, and there falls more than 175 feet in a horizontal distance of about 500 feet. Below the falls the creek drops more than 150 feet in 1½ miles. It is proposed by the parties who now claim water rights to divert water just above the falls and carry it through the ridge in a tunnel, thence along the west side of the valley for about 1½ miles below to a power house, where a fall of over 300 feet would be available. It is reported that about 800 feet of tunnel would be required. On September 10, 1913, about 60 feet of 4 by 6 foot tunnel had been driven. The formation was of soft rock which could be broken down with a pick without the assistance of explosives. The rock disintegrated rapidly on exposure to the air and it was found necessary to timber the tunnel as the work progressed. This work had been accomplished almost entirely by the efforts of one man.

Power Creek basin above the falls is steep and barren, furnishing but little ground storage near the surface, though the considerable flow that it is said to have throughout the winter indicates that the rock formation of the basin must offer considerable underground storage. After heavy rains the creek rises rapidly and floods frequently occur. The lower valley is thickly covered with spruce and hemlock trees, some of which reach a diameter of over 3 feet.

Power Creek offers a better opportunity for the development of power than any other stream near Cordova. It was originally considered as a source of power for lighting the town, but an agreement could not be reached between the power company and those who claimed water rights and a plant was installed on Humpback Creek instead.

Stream flow data are insufficient to make an accurate estimate of the amount of power that could be developed. But from the best data available it is estimated that the minimum flow for six months in the year would not be less than 75 second-feet. That flow would produce about 1,800 horsepower with an efficiency of 70 per cent at the wheel. During the remaining six months of the year the capacity might become 50 to 75 per cent less. Some storage could be obtained by a dam at the upper end of the gorge, which would increase the minimum capacity of the plant over that afforded by the natural minimum flow.

POWER CREEK NEAR CORDOVA.

This station was established July 25, 1913. The gage is a vertical staff on the right bank of the creek, about 300 feet above Ohman's cabin, 1½ miles from Eyak Lake, and about 6 miles from Cordova. (See No. 2, Pl. X, p. 72.)

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Measurements were made by wading at a section just below the gage.

The discharge at the proposed point of diversion for power development, which is about 1½ miles above the gage, was about 25 per cent less than at the regular measuring section on September 10, 1913, as determined by measurement. The actual difference in run-off at the two sections was probably somewhat less, as the bed of the creek at the upper section appeared to be more porous, thus affording a greater opportunity for underground flow.

Discharge measurements of Power Creek near Cordova, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 25	6.90	518	Oct. 6	6.25	262
Sept. 10	5.83	137	Nov. 15	5.76	140
10		[a] 109			

[a] This measurement was made above the falls to determine the difference in discharge at the two sections.

Daily gage height, in feet, and discharge, in second-feet, of Power Creek near Cordova, Alaska, for 1913.

[A. R. Ohman, observer.]

	July.		August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1										
2										
3										
4										
5										
6										
7			6.70	433						
8			7.07	698						
9			7.87	[a] 1,030			5.99	187		
10			7.14	633	5.83	147	5.86	154	5.57	96
11			6.85	496	5.83	147	5.84	149	5.63	106
12			6.74	450	6.17	240	5.80	140	6.51	359
13			6.72	441	6.39	314				
14			6.98	656	7.11	617			6.01	193
15					7.15	638			5.76	132
16										
17										
18										
19			6.38	311						
20			6.42	325						
21			6.45	336						
22			6.52	363						
23			6.49	351						
24			6.58	385						
25	6.90	418	6.60	393						
26	7.02	674	6.92	427						
27			9.88	[a] 2,360						
28										
29										
30	6.85	496								
31	6.90	418								

[a] Approximate.

NOTE.—Daily discharge computed from a rating curve fairly well defined below 700 second-feet.

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PRINCE WILLIAM SOUND REGION.

GENERAL FEATURES.

Prince William Sound is an irregular-shaped bay reaching northward from the head of the Gulf of Alaska. (See Pl. X.) It extends from Cordova on the east to the head of Passage Canal on the west, a distance of 102 miles. In a north-and-south direction it reaches from the head of College Fiord to the lower end of Montague Island, a distance of 104 miles. The entrance to the sound lies between Hinchinbrook and Montague islands. The shore line is broken by a succession of fiords, bays, and inlets, and many islands break the continuity of the sound, particularly in its western part.

The topographic features of the mainland are particularly rugged. The coast is rocky and precipitous and rises rapidly to the summit of the Chugach Mountains, which nearly encircle the sound. Most of the higher valleys are occupied by glaciers, many of which extend down to sea level. The majority of the peaks near the coast are from 2,000 to 5,000 feet in elevation. Farther north, toward the axis of the range, they reach altitudes of over 10,000 feet.

Grant and Higgins [1] state that "the topography of Prince William Sound is that of a maturely eroded mountainous district, with the forms of river erosion modified by ice erosion. Into such a district the sea has come, filling the main basin of the sound and extending far up the valleys that lead into it."

The streams entering the sound drain small areas, and most of them are 1 to 5 miles in length. Lowe River is nearly if not the largest. It is 30 miles long and drains an area of probably less than 200 square miles. Practically without exception they all have their source in snow fields and glaciers. Their flow is subject to wide variation from summer to winter. The rapid meeting of the glaciers and snow banks, together with a heavy rainfall in the summer, produces excessive rates of run-off. In the fall and winter the flow from the accumulated ice and snow in the mountains rapidly decreases and the precipitation comes mostly in the form of snow. There is some rainfall and melting of snow during the winter, but the flow probably depends largely on the draining of underground channels. The prevailing rock formation is slate and graywacke, with only a thin covering of soil and other loose material. The opportunity for underground storage is therefore likely to be limited, and such sources would, as a rule, become quickly exhausted as soon as the inflow from the surface was cut off by low temperatures.

Valdez and Cordova are the principal towns in the Prince William Sound region. Valdez, which is situated at the head of Port Valdez,

[1] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 15, 1910.

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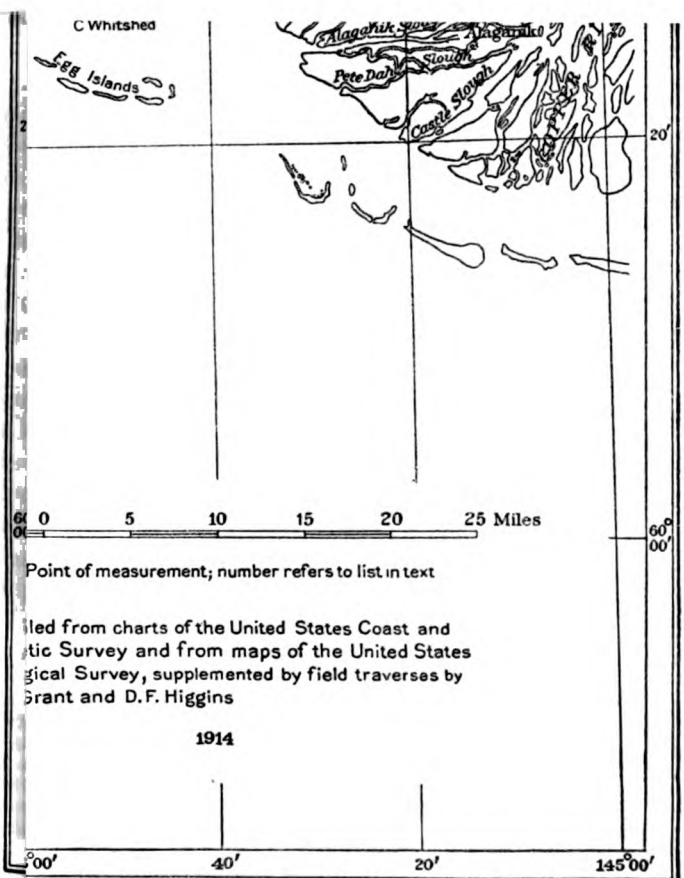

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is the supply point for the Valdez mining district and adjacent territory and is the headquarters for the Alaska Road Commission and the military telegraph line through the Copper River valley to Fairbanks and the Yukon Valley. It is also the terminal for the Valdez-Fairbanks wagon road. The population according to the 1910 census was 810.[1] Cordova, which stands near the southeast corner of the sound, had a population of 1,152 in 1910, but that was during the construction of the Copper River & Northwestern Railway, which brought here a population much larger than the present population of the town. The commercial life of the town now depends on its being the transfer point between ocean-going boats and the railroad leading to the Copper River valley. Other settlements in this region are Orca, Landlock, Ellamar, Fort Liscum, Golden, and Latouche.

MINERAL RESOURCES.

The mineral resources of Prince William Sound region lie mainly in its gold and copper ores.[2] Regular shipments of copper ore are made from the Beatson-Bonanza, mine on Latouche Island, and from the Ellamar mine, at Ellamar.[3] Small quantities of ore have also been shipped from various other properties, notably those near Landlocked Bay and Port Fidalgo. Copper prospects are widely distributed throughout the region and considerable development work has been done, but the productive mines are so far limited to those mentioned above.

The auriferous quartz veins so far discovered lie principally in the area surrounding Port Valdez,[4] and since 1910 prospecting has been actively carried on. The Cliff mine has been worked almost continuously since the installation of the first mill, in April, 1910. The present mill has six 1,450-pound Nissen stamps and is the only mill that is being operated uninterruptedly. Several small mills have recently been installed in the district, and reports indicate that further development work will be continued. Though there is sufficient reason to believe that the gold lodes of this district will furnish ore for the successful operation of many small mills, development work has not yet assured the hope of any large mines. Gold-quartz veins have also been discovered near Port Wells,[5] and for the past year considerable excitement has prevailed in that section, but up to the present time all the properties are in the development stage.

[1] This includes only the incorporated town; with the adjacent settlement its population is now probably 1,200 to 1,500.

[2] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, 1910.

[3] See Capps, S. R., and Johnson, B. L., The Ellamar district, Alaska: U. S. Geol. Survey Bull. 605, 1915.

[4] Brooks, A. H., Gold deposits near Valdez: U. S. Geol. Survey Bull. 520, pp. 108-130, 1912.

[5] Johnson, B. L., The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, pp. 195-236, 1914.

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TIMBER.

The mainland shores and most of the islands of Prince William Sound are generally covered with a thick growth of trees up to an elevation of 1,000 feet or more. Spruce is the prevailing growth, and some of it is of a size and quality to produce a good grade of sawed lumber. Much of it, however, is stunted and of an inferior quality. The United States Forest Service estimates that there is nearly 3.5 billion feet board measure of timber in the Prince William Sound region.

The timber resources of this region will probably be used chiefly for the production of wood pulp. These timbers are said to be suitable for such uses, and the possibilities for the successful introduction of the pulp industry have been more or less considered, but so far as is known no steps have yet been taken toward the construction of mills. The manufacture of wood pulp was recently commenced in southeastern Alaska. One small mill was being erected in the summer of 1913, but it is reported that this project was abandoned and that no immediate development of the wood-pulp industry is in prospect.

The forests of Prince William Sound are all included in the Chugach National Forest Reserve, which is under the control of the Forest Service of the United States Department of Agriculture. The local administration of this reserve is under the charge of the forest supervisor at Ketchikan, who has a suboffice at Cordova. Such timber as it is considered advisable to cut within the reserve will be sold by the Forest Service at a price not less than the appraised value. Lots exceeding $100 in value must be advertised for 30 days and sold to the highest bidder.

GAGING STATIONS AND MEASURING POINTS.

Points at which gaging stations were maintained or discharge measurements made on streams tributary to Prince William Sound in 1913, are listed below. The numbers correspond to those given on Plate X.

1. Salmon Creek below forks.[1]
2. **Power Creek near Cordova.**[2]
3. **Humpback Creek near Cordova.**
4. Snyder Falls Creek at mouth.
5. Wesley Falls Creek at elevation 600 feet.
6. Parsons Falls Creek at mouth.
7. Robinson Falls Creek at mouth.
8. Unnamed stream tributary to Sheep Bay.
9. Unnamed stream tributary to Port Fidalgo.
10. Unnamed stream tributary to Fish Bay.
11. Unnamed stream tributary to Fish Bay.
12. Chisna Creek at mouth.
13. Horsetail Falls Creek at mouth.
14. Lagoon Creek at mouth.

[1] This stream enters the Pacific Ocean east of Prince William Sound through Alaganik Slough.
[2] This stream enters the Pacific Ocean east of Prince William Sound through Eyak Lake and Eyak River.

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15. Reynolds Creek at elevation 250 feet.
16. **Gladhaugh Creek at elevation 250 feet.**
17. Gladhaugh Creek at elevation 125 feet.
18. **Bottle Creek at mouth.**
19. **Duck River at mouth.**
20. Solomon Gulch above upper dam.
21. Solomon Gulch at mouth.
22. Lowe River at lower end Heiden Canyon.
23. Mineral Creek between Brevier and Glacier creeks.
24. Mineral Creek at lower canyon.
25. Brevier Creek at elevation 150 feet above mouth.
26. Glacier Creek at elevation 100 feet above mouth.
27. East Fork of Mineral Creek at elevation 900 feet above mouth.
28. **Gold Creek above falls.**
29. Gold Creek at mouth.
30. **Uno Creek at mouth.**
31. McAlister Creek at mouth.
32. Unnamed creek tributary to Eaglek Bay.
33. **Davis Creek at Golden.**
34. **Avery River near Golden.**
35. Lagoon Creek at lake outlet.
36. **Hobo Creek at mouth.**
37. Hummer Creek at mouth.
38. Unnamed creek tributary to Hummer Bay.

NOTE.—Black-faced type indicates regular gaging stations; light-faced type points of miscellaneous measurements.

ORCA BAY.

GENERAL FEATURES.

Orca Bay is the easternmost arm of Prince William Sound. Near its head a passage known as Orca Inlet leads southward to the Gulf of Alaska. The town of Cordova is on the east shore of Orca Inlet about 5½ miles from Orca Bay. Ocean-going vessels reach the harbor of Cordova by way of Orca Bay and Orca Inlet. Orca post office and cannery is situated about 3 miles above Cordova on the same side of the inlet.

Humpback Creek enters Orca Inlet from the east about 5 miles north of Cordova. It heads in rugged mountains 3,000 to 4,000 feet high and falls rapidly to sea level. The hydroelectric plant of the Cordova Power Co. is situated at the mouth of the creek. (See pp. 105–106.)

Orca Bay terminates at its head in a gravel and silt flat 2 to 3 miles long and a mile or more in width, known as Nelson Townsite. The flats have been formed by glacial wash brought down and deposited by Rude River.[1]

Rude River is said to head in a large glacier 8 or 10 miles from tide water, and occupies a broad silt-floored valley throughout its course. It is reported that the glacier from which it takes its source reaches well down into the main valley, precluding any opportunity for power

[1] Called also Cordova River.

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development. Three streams, Snyder Falls, Wesley Falls, and Parsons Falls creeks, enter Rude River within 3 miles of tidewater.

Snyder Falls Creek enters from the east near Cooper's cabin just above high-tide level. It has its source in small hanging glaciers and deep snow banks at an elevation of over 1,000 feet above sea level. Most of the flow is collected in a small cirque at an elevation of about 800 feet. The creek has cut a deep channel near the cirque outlet, and thence to Rude River valley, a distance of less than a mile, it flows in a series of falls and rapids through a rock-walled canyon most of the way. At several points along its course the water could be easily diverted to a pressure pipe and carried to the mouth of the creek.

Wesley Falls Creek enters Rude River about 1 mile above Snyder Falls Creek and from the same side. Its headwaters, like those of Snyder Falls Creek, are among rugged, steep-sloped mountains, with but little soil or vegetation to regulate the run-off. Water could be easily diverted at an elevation of about 600 feet. The south side of the valley offers a fair opportunity for the construction of a pipe line leading to the mouth of the creek, a distance estimated to be less than a mile.

Parsons Falls Creek joins Rude River from the west about 1 mile above Wesley Falls Creek. It drains a somewhat larger area than either Snyder Falls Creek or Wesley Falls Creek. Its headwater region is less rugged and barren. Timber line extends to a higher altitude and there are probably no glaciers in the basin. It is formed by the union of several branches, below which it falls rapidly through a distance of several hundred feet and then takes a moderate grade to Rude River.

Robinson Falls Creek is a small stream from the west, about opposite Snyder Falls Creek.

There is no opportunity to develop storage on any of the streams entering Orca Inlet, except possibly small reservoirs that might be of sufficient capacity to equalize the daily flow.

HUMPBACK CREEK NEAR CORDOVA.

This station was established May 20, 1913. The gage is located at the spillway of the Cordova Power Co.'s dam.

Measurements of discharge were made in the spillway, which is located on the left side of the dam. It is 7 feet deep and 20 feet wide and is of sufficient capacity to carry the flow of the creek at all times except at extreme flood stages, when the excess flow passes over the crest of the dam. The average quantity of water diverted through the base of the dam to the pipe line for the operation of the wheel was approximately determined by taking the mean of several measurements made just below the tailrace.

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Discharge measurements of Humpback Creek near Cordova, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 20	1.28	44	Sept. 9	0.83	10.0
May 21	1.28	38	Oct. 7		[a] 30
July 28	1.34	46	Nov. 16		[a] 17.7
July 30	1.80	97			

[a] These measurements were made in the creek below the dam. All other measurements were made at the spillway.

Discharge measurements below tailrace of Cordova Power Co.'s plant in 1913.

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
May 21	4.5	Sept. 9	6.3
July 28	3.5	Oct. 7	4.0

Daily gage height, in feet, and discharge, in second-feet, of Humpback Creek near Cordova Alaska, for 1913.

[Chas. Cochran, observer.]

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1										
2			1.56	70						
3					1.65	80	1.35	[a] 48		
4										
5							1.38	50		
6					1.78	[a] 96				
7			1.56	70						
8					1.65	80				
9							2.00	122	0.83	10.0
10										
11					1.56	70				
12										
13			1.55	68			1.21	35		
14										
15										
16					1.75	91	1.10	26		
17										
18							1.10	26		
19			1.57	[a] 71	2.32	164				
20	1.28	[a] 41			2.60	[a] 200				
21	1.28	[a] 41					1.10	26		
22										
23			1.56	70						
24					1.80	97				
25							1.10	26		
26							1.42	54		
27	1.67	82					5.85			
28			1.56	70	1.33	46				
29	1.62	[a] 76			2.00	122	1.70	85		
30					1.85	103				
31										

[a] Entire flow passing over spillway. To obtain the natural flow of the creek on other days add 4.6 second-feet, which is the average flow diverted through base of dam for use at power plant.

NOTE.—Discharge computed from a rating curve that is fairly well defined below 120 second-feet.

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MISCELLANEOUS MEASUREMENTS.

The results of discharge measurements made at miscellaneous points on streams near Orca Bay are shown in the following table:

Miscellaneous measurements on streams near Orca Bay in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
July 29	Snyder Falls Creek	Rude River	Mouth	99
28	Wesley Falls Creek	do	Elevation 600 feet	79
29	Parsons Falls Creek	do	Mouth	[a] 150
29	Robinson Falls Creek	do	do	8.3

[a] Estimated.

SHEEP BAY.

Sheep Bay is a northern arm of Orca Bay. It is about 8 miles long and is situated between Simpson Bay on the east and Port Gravina on the west. Entering it from the west about midway of its length is a small unnamed creek that would offer a favorable site for a small power plant. At an elevation of about 700 feet is a lake with an estimated area of about 100 acres. The outlet is through a narrow rock canyon, where a dam could be easily constructed that would raise the lake level 15 or 20 feet. The lake is nearly surrounded by high rock walls rising 1,000 to 2,000 feet to the summit of the ridge. Below the lake the creek falls about 300 feet in a distance of about one-half mile; it then takes a moderate grade through a meadow-like part of the basin for a distance of probably less than one-half mile, and thence to the bay, a distance estimated to be about 1,000 feet, it falls nearly 250 feet. Just before entering salt water it has a sheer drop of over 150 feet. The discharge at the outlet of the lake on July 30, 1913, was estimated to be between 70 and 80 second-feet.

PORT FIDALGO.

Port Fidalgo is a large eastward arm of Prince William Sound, lying between Port Gravina and Valdez Arm. From Porcupine Point to the extreme head of Port Fidalgo the distance is about 25 miles, and the average width about 3 miles. The streams from the south, as far east as Whalen Bay, are small and would probably not be worth considering as sources of power. Beyond Whalen Bay to the east the streams were not visited, though there are said to be several that carry considerable water, but no information is available regarding their value for power development.

About 6 miles from the extreme head of Port Fidalgo an unnamed stream enters from the north. Its lower course for 3 or 4 miles is through a broad glacial valley, and its wide flood plain of overwash silt and sand and the muddy appearance of the water give evidence of a glacial source. It heads east of Mount Denson ("Rooster Comb"),

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and as seen from the mouth appears to come from the mountains in a narrow, precipitous valley, though glaciers may reach well down to the level of the enlarged valley leading to salt water. A measurement made near the mouth on August 2, 1913, gave a discharge of 205 second-feet.

Fish Bay is a small northern projection from Port Fidalgo opposite Irish Cove. It has two tributary streams of importance. The larger of the two enters at its extreme upper end. It is sometimes called Falls Creek, for appropriate reasons, but that name is not well established and it is generally considered an unnamed stream. About 1½ miles from the mouth it forks. The eastern fork is the larger of the two, and on August 2, 1913, the discharge was estimated to be about twice that from the west. A measurement made just below the forks on the above date showed a discharge of 70 second-feet. As seen from the spur between the two branches, each appears to head in large glacial cirques that may perhaps contain small lakes. On leaving the cirques both streams fall nearly vertically through a height variously estimated from 1,000 to 2,000 feet. The streams unite about a mile below the foot of the escarpment. Because of the immense fall the east fork is locally considered to afford an exceptional opportunity for water-power development. This opinion would be justified if a sufficient flow could be maintained, but it is doubtful if the discharge during the winter or even for much of the remainder of the year would be nearly as great as at the time of the above measurement, which was made during the season when the melting of ice and snow in the mountains would naturally be at a maximum.

How much less the discharge at the head of the falls would be than at the forks can be determined only by actual measurements. Even though the difference was but little during warm weather it might become considerable in the winter, when the lower temperatures at the higher altitudes might reasonably be expected to cut off almost entirely the flow to the upper basin, while at an elevation of 1,500 feet or more below, because of the increased possibilities for inflow from deep-seated underground sources, the supply might be sufficient to warrant power development.

The valley below the falls is heavily timbered and very difficult to travel through. The creek has a moderate grade for a coastal stream, but it flows through rock canyons at several points and there are a few falls and rapids that prohibit travel along the creek except at low water and then only with considerable difficulty. In some places the valley is narrow with steep slopes; in others it widens with bench-like formations at varying elevations above the water level.

The next stream enters Fish Bay near the extreme southeast corner. It heads in a ridge about 2,000 feet high southeast of Landlocked Bay, at a distance estimated to be about 3 miles from its mouth.

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The topography is less rugged than that typical of most coastal streams. There are no glaciers in the basin. The flow is dependent on rainfall and melting snow and is probably very low for much of the year. There is a small lake at an elevation of about 950 feet that could be made to furnish storage that would be very important for a small water-power plant. Below an elevation of about 900 feet there is evidence of but little inflow.

A measurement made at the above elevation on August 1, 1913, gave a discharge of 3.7 second-feet.

LANDLOCKED BAY.

GENERAL FEATURES.

Landlocked Bay is a northern arm of Fidalgo Bay between Fish Bay on the east and Boulder Bay on the west. Four small streams—Chisna, Horsetail Falls, Lagoon, and Reynolds creeks—enter Landlocked Bay.

Chisna Creek rises on the north slope of Billygoat Mountain at an elevation of about 2,200 feet. It is about 1½ miles long and flows north, entering directly opposite the Three Man Mining Co.'s camp. The Chisna Consolidated Mines Co. installed a small water-power plant at the mouth of the creek several years ago. (See p. 107.)

Horsetail Falls Creek enters Landlocked Bay about one-half mile east of Chisna Creek. It falls nearly vertically through a height of about 500 feet just before entering the bay. There is a small pond at an elevation between 900 and 1,000 feet. The discharge of the creek becomes very low in the fall after the beginning of cold weather, and probably during much of the winter it is practically dry. On October 8 and also on November 18 the flow of the creek was observed by the writers to be very low, probably less than 1 second-foot on each of the above dates.

Lagoon Creek is the largest stream tributary to the coast between Fish Bay and Galena Bay. It heads opposite Bottle Creek and flows southeastward, entering the head of Landlocked Bay through the Lagoon. For the first mile above the mouth the creek flows through a narrow, steep-sloped valley and in that distance falls about 450 feet. It is made up of a series of cataracts, rapids, and small gravel-filled basins. Above, the valley broadens considerably and the creek has a more moderate grade. At low and medium stages the water is clear and is probably derived from rain and melting snow. It is said that there are no glaciers within the basin. The development of power would be dependent on the daily flow of streams, as there is but little opportunity for storage. Several measurements of discharge were made at the mouth (see table, p. 81), where the flow would naturally be somewhat greater than at a higher altitude where a diversion would be made for power development. On October 8,

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1913, the discharge at an elevation of about 450 feet was estimated to be 25 per cent less than at the mouth.

Reynolds Creek rises at an elevation of about 2,500 feet and flows southward, entering Landlocked Bay about one-fourth mile northeast of the camp of the Three Man Mining Co. The basin is nearly circular and covers an area of 1.4 square miles. It is a clear-water stream and fluctuates rapidly during rainy periods and in warm weather when there is snow in the headwaters. It has been considered as a source of power by the Three Man Mining Co. Water would be diverted at an elevation of about 240 feet and carried along the west side of the valley in a flume 1,500 feet long. About 400 feet of pipe would be required to convey the water from the flume to a power house at the beach. A gage was installed on the creek on July 31, 1913, at an elevation of about 250 feet, and several readings were made during the summer by W. A. Dickey, but because of shifting channels and insufficient measurements to determine time and amount of the various changes, it is not considered advisable to publish estimates of flow except at times of measurements. The least discharge measured was 2.4 second-feet, on November 18. Under a head of 240 feet that rate of flow would develop 46 horsepower at an efficiency of 70 per cent. It is not unlikely that a lower stage was reached for short periods during the summer and fall between rains. What the flow would be during the winter can only be determined by frequent measurements.

MISCELLANEOUS MEASUREMENTS.

The only records of flow on streams tributary to Landlocked Bay are the following miscellaneous measurements:

Miscellaneous measurements near Landlocked Bay in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. miles*	*Sec.-ft.*
Aug. 1	Chisna Creek	Landlocked Bay	Mouth	4.2	0.9	4.67
1	Horsetail Falls Creek	do	do	4.2	.7	6.00
July 31	Lagoon Creek	do	do	67		
Oct. 8	do	do	do	20		
Nov. 18	do	do	do	14.4		
July 31	Reynolds Creek	do	Elevation 250 feet	12.7	1.2	10.58
Oct. 8	do	do	do	3.3	1.2	2.75
Nov. 18	do	do	do	2.4	1.2	2.00

GLADHAUGH CREEK.

GENERAL FEATURES.

Gladhaugh Creek enters Virgin Bay about one-fourth mile north of Ellamar. The basin occupies a circular area 1.6 square miles in extent and reaches its highest point on Ellamar Mount (ele-

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vation 2,700 feet) to the north. In its upper part the bounding ridge rises precipitously and the flow reaches the main stream in many ill-defined channels from a cirquelike basin.

At the lower end of the cirque there is a nearly vertical fall of about 40 feet. From the foot of the falls to the mouth, a distance of about 1 mile, the creek falls about 200 feet. After about the middle of June, when the snow has left the basin, the flow is dependent on the rainfall, and reaches a very low stage much of the time.

The Ellamar Mining Co. diverts water from Gladhaugh Creek about one-half mile from the mine, at an elevation of about 125 feet. It is carried to the camp in an iron pipe and there used for domestic and boiler purposes.

The stream has been considered as a possible auxiliary source of power for use at the Ellamar mine. Such records as have been obtained show that for much of the time the flow would be insufficient to warrant the installation of a plant.

GLADHAUGH CREEK AT ELEVATION 250 FEET.

On May 14, 1913, a gage was installed on the left bank of Gladhaugh Creek, about 150 feet above the falls, and at an elevation of 250 feet.

Discharge measurements of Gladhaugh Creek at elevation 250 feet in 1913.

[Drainage area, 0.6 square mile.]

Date.	Gage height.	Discharge.	Discharge per square mile.
	Feet.	*Sec.-feet.*	*Sec.-feet.*
May 14	1.74	9.7	16.17
Aug. 2	1.44	2.4	4.00
Oct. 8	1.52	2.0	3.33

Daily gage height and estimated discharge of Gladhaugh Creek at elevation 250 feet in 1913.

[Observer L. W. Storm.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 14	1.75	10.2	June 19	1.74	9.8
May 16	1.78	11.3	July 13	1.53	4.0
May 20	1.72	9.0	July 26	1.73	9.4
May 24	1.75	10.2	Aug. 2	1.44	2.4
May 31	1.83	13.3	Oct. 8	1.52	2.0
June 6	1.85	14.1			

GLADHAUGH CREEK AT ELEVATION 125 FEET.

In order to determine the relation between the run-off at elevation 250 feet and at elevation 125 feet a gage was installed at the lower elevation on August 2, 1913, but as daily records at the point were

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not kept the only days on which the flow at the two stations can be compared are August 2 and October 8, when the discharge was measured at each station. The measurements show that on those dates the discharge at the lower gage was 45 per cent greater than at the upper.

Discharge of Gladhaugh Creek at elevation 125 feet in 1913.

[Drainage area, 1 square mile.]

Date.	Discharge.	Discharge per square mile.
	Sec.-feet.	*Sec.-feet.*
Aug. 2	3.5	3.50
Oct. 8	2.9	2.90
Nov. 18	2.0	2.00

GALENA BAY.

GENERAL FEATURES.

Galena Bay is an eastward projection of Valdez Arm, lying between Jack Bay on the north and Tatitlek Narrows on the south. It is about 6 miles long, with an average width of about 1 mile. The only streams of importance entering the bay are Bottle Creek and Duck River.

BOTTLE CREEK.

GENERAL FEATURES.

Bottle Creek drains an area comprising approximately 12 square miles north of Landlocked Bay. It enters Galena Bay near its extreme southeast corner at the Galena Bay Mining Co.'s camp. The bounding ridges are steep and rugged, but much of the inclosed area is of low relief and swampy. Between Gumboot Basin and the bay the creek falls more than 150 feet. Gumboot Basin is a flat expanse beginning about 1 mile from the bay and extending eastward along the creek for a distance of 2 to 3 miles, varying in width from one-half mile to 1 mile. The main tributaries are from the south. Copper Creek, which joins Bottle Creek near the upper end of Gumboot Basin, rises in Copper Lake about 1½ miles from the main stream, at an elevation of about 750 feet. Copper Lake covers an area of about 100 acres and receives its inflow mainly from the northeast slope of Copper Mountain (elevation 3,946 feet). East of Copper Creek valley is Vesuvius Valley, which drains into Bottle Creek near the lower end of Gumboot Basin. Mallard Lake is situated near the lower end of Vesuvius Valley at an elevation of about 200 feet. The Galena Bay Mining Co., which has copper prospects at the upper end of the valley, has installed a hydroelectric plant on Bottle Creek. (See p. 107.)

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BOTTLE CREEK AT GALENA BAY.

This station was established May 13, 1913. The gage was located near the mouth of the creek on the left bank. It was read at or near time of low tide. At high tide the readings were affected by backwater from the bay. Measurements of discharge were made by wading below the gage. The channel remained permanent during the period covered by the records.

Discharge measurements of Bottle Creek at Galena Bay in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 13	1.93	155	Oct. 11	1.14	30
Aug. 3	1.41	61			

Daily gage height, in feet, and discharge, in second-feet, of Bottle Creek at Galena Bay for 1913.

[Drainage area, 12 square miles; G. L. Banta, observer.]

Day.	May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	1.80	127	1.90	148	1.56	84
2	.....	.....	1.78	123	1.87	142	1.52	77
3	.....	.....	1.85	138	1.88	144	1.41	60
4	.....	.....	2.05	181	1.90	148	1.38	56
5	.....	.....	2.20	215	1.92	152	1.36	54
6	.....	.....	2.30	238	1.86	140	1.45	66
7	.....	.....	2.15	204	1.82	131	1.40	59
8	.....	.....	2.18	210	1.80	127	1.36	54
9	.....	.....	2.42	267	1.76	119	1.45	66
10	.....	.....	2.30	238	1.70	108	1.60	90
11	.....	.....	2.05	181	1.65	99	1.40	59
12	.....	.....	1.95	159	1.65	99	1.35	52
13	1.93	155	2.38	257	1.65	99	1.30	46
14	1.86	140	2.40	262	1.60	90	1.20	35
15	1.84	135	2.35	250	1.60	90	1.14	30
16	2.04	179	2.33	245	1.70	108	1.05	24
17	1.98	166	2.25	226	1.75	118	1.00	20
18	2.18	210	2.20	215	1.85	138	.98	19
19	2.04	179	2.05	181	2.05	181	1.02	21
20	1.80	127	2.16	206	2.80	362	1.00	20
21	1.85	138	2.05	181	2.45	274	1.03	22
22	1.92	152	2.18	210	2.10	192	1.10	27
23	2.05	181	2.10	192	1.95	159	1.20	35
24	1.90	148	2.05	181	1.85	138	1.10	27
25	1.80	127	.....	178	1.74	116	1.12	29
26	1.74	116	.....	174	1.70	108	2.20	215
27	2.20	215	2.00	170	1.67	103	3.20	462
28	2.16	206	2.03	177	1.65	99	2.80	362
29	2.05	181	1.95	159	1.62	94	1.70	108
30	1.85	138	1.90	148	1.58	87	1.30	46
31	1.80	127	.....	.....	1.55	82	1.25	40
Mean discharge		159		196		135		76.3
Second-feet per square mile		13.3		16.3		11.2		6.36
Run-off (depth in inches on drainage area)		9.40		18.2		12.9		7.33
Maximum		215		267		362		462
Minimum		116		123		82		19
Accuracy		B.		B.		B.		B.

NOTE.—Discharges computed from a rating curve fairly well defined below 200 second-feet.

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A. DAM SITE AT OUTLET OF SILVER LAKE.

B. FALLS ON DUCK RIVER NEAR SILVER LAKE.

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PORT VALDEZ, LOOKING NORTH.

Shoup Bay near center.

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DUCK RIVER.

GENERAL FEATURES.

Duck River has its source in Silver Lake at an elevation of about 250 feet above sea level. (See Pl. XI, *A*.) It is estimated to be about 2 miles long and enters Galena Bay at the northeastern corner through the Lagoon. The river has a uniformly steep grade with several very beautiful waterfalls near the lake. (See Pl. XI, *B*.) It is bounded on the north by a steep-sloped ridge, which reaches an altitude of about 4,000 feet opposite the lake outlet and increases in elevation eastward. To the south the topography adjacent to the river is irregular, with a more gradual ascent to the summit. The valley is densely timbered except a few small meadow-like openings on the south which are swampy and usually contain small ponds.

Duck River and Silver Lake offer the most favorable opportunity for water-power development in the Prince William Sound region, so far as is known by the writers. Silver Lake is estimated to be between 3 and 5 miles long and to have an average width of about 1 mile. The shore rises abruptly on all sides and the water is said to be deep even a few feet from the edge. The lake, as seen from the outlet, is surrounded on all sides by high mountains that reach their greatest elevations near the head, where they are particularly rugged and precipitous. Some distance from the outlet the lake bends to the south, cutting from view its upper part. The lake lies beyond the area mapped and it is impossible to estimate the extent of its drainage with reasonable accuracy, but the run-off, as shown by the measurements listed below (also see fig. 4), is much greater than would be expected from the available information concerning the general limits of the basin. The waters of Duck River were quite turbid at the time of each measurement, though undoubtedly much less so than they would have been without the settling effect from the lake. The appearance of the water and the apparent high run-off leads to the conclusion that a considerable proportion of the inflow must be from active glaciers that are reported to exist in the upper part of the basin.

The topography at the outlet of the lake is favorable for the construction of a dam up to a height of 100 feet or more. (See Pl. XI, *A*.) The lake level could be raised 30 feet by a dam about 60 feet long. Bedrock lies near the surface and a solid foundation for a dam is probably obtainable. Considerable substorage could be obtained if desired by placing the intake pipe below the normal lake level.

It is reported that water could be conducted from the lake outlet to a power house at sea level on the lagoon, about one-half mile south of the mouth of Duck River by a pipe line about 1½ miles long.

Parties who claim water rights on the river state that from a knowledge obtained by weir measurements made during the spring

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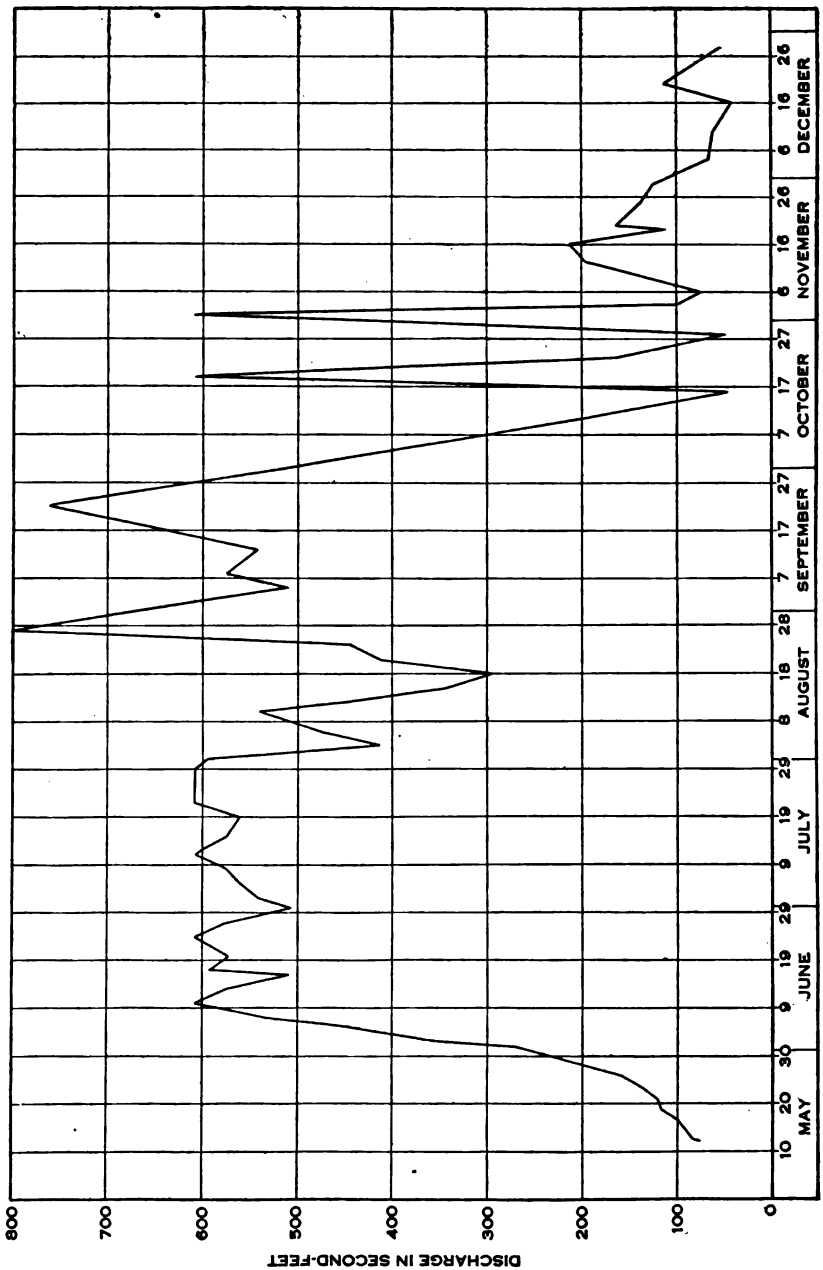

FIGURE 4.—Hydrograph of Duck River.

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of 1913, together with general observations at different seasons of the year, they have estimated the minimum flow to be not less than 30 second-feet.

The average yearly flow of Duck River, as determined from the following records and an assumed flow of 30 second-feet for the remainder of the year, is about 240 second-feet. The facilities for storage are believed to be sufficient to maintain a uniform flow at the above rate. With an efficiency of 70 per cent at the wheel, 240 second-feet of water under a head of 250 feet would produce nearly 4,800 horsepower. More records should be procured, particularly during the winter months, on which to base final plans for development.

DUCK RIVER AT GALENA BAY.

This station was established May 13, 1913, on the right bank of the creek about 600 feet above the mouth. Gage readings were made at intervals of four or five days for the remainder of the year.

Measurements were made by wading at low and medium stages and from a boat at high stages. The channel remained permanent during the period covered by the records.

The difference in discharge of the river at the outlet of the lake and at the measuring section near the mouth was not determined by actual measurements, but there was no evidence of much inflow between these points.

Discharge measurements of Duck River at Galena Bay in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 12	1.55	76	Oct. 12	1.90	149
13	1.61	82	Nov. 19	1.73	112
Aug. 3	2.54	409			

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Daily gage height, in feet, of Duck River at Galena Bay for 1913.

[G. L. Banta, observer.]

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		2.25					2.85	
2		2.42	2.75		2.85			
3				2.54			1.70	
4						2.50		1.45
5		2.60	2.78		2.70			
6				2.65			1.50	
7		2.74						
8			2.80		2.80			
9								
10		2.85		2.75				1.40
11			2.85					
12	1.55		2.84	2.60		1.90	2.05	
13	1.61	2.80			2.75			
14								
15			2.80	2.40				
16	1.68	2.70				1.10	2.10	1.10
17		2.83						
18				2.30				
19	1.78		2.78			2.85	1.73	
20		2.80					1.95	1.75
21	1.80			2.54				
22			2.85		3.05			
23	1.85					1.95		
24		2.85		2.60				
25			2.85				1.85	
26	1.94							
27		2.80		3.10				
28	2.05					1.20		1.30
29			2.85				1.80	
30		2.70			2.70			
31			2.83					

NOTE.—Discharge computed from a rating curve well defined between 60 and 500 second-feet.

Daily discharge, in second-feet, of Duck River at Galena Bay for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		272					608	
2		350	540		608			
3				412			100	
4						390		64
5		445	560		507			
6				476			70	
7		533						
8			573		573			
9								
10		608		540				59
11			608					
12	76		601	445		149	196	
13	85	573			540			
14								
15			573	340				
16	97	507				40	212	40
17		594						
18				293				
19	118		560			608	107	
20		573					164	111
21	122			412				
22			608		760			
23	136					164		
24		608		445				
25			608				136	
26	161							
27		573		800				
28	196					44		50
29			608				122	
30		507			507			
31			594					

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PORT VALDEZ.

GENERAL FEATURES.

Port Valdez is a northeastern fiord of Prince William Sound. It is about 14 miles long and about 3 miles in average width. It trends east and west, bending to the south at the western end, and terminates in Valdez Narrows, with a minimum width of about 1 mile. The fiord is 600 to 800 feet in average depth, with but little shallow water except at the head, where large glacial streams are building up their delta. Port Valdez is surrounded by high, rugged mountains (see Pl. XII, p. 85), the main Chugach Range to the north and a spur of it to the south. On the north the mountains have steep slopes and have many sharp rocky peaks, some reaching altitudes of nearly 7,000 feet. The mountains south of the bay are not so high, ranging from 3,000 to 5,400 feet in elevation. Many of the higher valleys on the north are filled with glaciers. Valdez Glacier is the largest body of ice in the region. It is more than 15 miles long, nearly 2 miles in average width, and terminates about 3½ miles northeast of the town of Valdez at an elevation of 250 feet above sea level. The only glacier reaching tidewater is Shoup Glacier at the head of Shoup Bay. There are a few small glaciers among the higher of the peaks to the south.

The principal streams tributary to Port Valdez are Solomon Gulch from the south, Lowe River and Valdez Glacier streams at the head, and Mineral Creek, Gold Creek, and Uno Creek from the north. There are many other streams entering the bay, but they drain small areas and carry sufficient water for power development only during the spring and early summer, when the snow in the mountains is rapidly melting, or at times of heavy rains. (See p. 97 for list of miscellaneous measurements.)

SOLOMON GULCH.

Solomon Gulch offers a more natural if not a greater opportunity for the development of water power than any stream entering Port Valdez. It has its source in glaciers 6 or 8 miles from the bay and occupies a broad, gravel-filled basin for most of its length. About three-fourths of a mile from the mouth of the creek the basin is contracted by a spur from the east, and the stream for the remainder of its course flows through a rock-walled canyon in a series of falls with a drop of over 500 feet. This power is now being utilized by two companies who have installed hydroelectric plants and transmit current to Valdez. These plants are described on pages 107–108. The basin is without forests except a few small scattered spruce. The snowfall is very heavy in the upper basin and the summer runoff is likely to be excessively high. (See Pl. III, *B*, p. 36.) The

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minimum flow probably occurs during March and April, though the run-off probably becomes very low by the 1st of February. Several miscellaneous measurements were made on the creek and are listed in the table on page 97. The lowest flow measured was 12.7 second-feet on May 7, 1913, but this, owing to melting snow, was undoubtedly greater than the minimum for the winter. A conservative estimate of the minimum would be less than 10 second-feet. It is estimated that if all the storage that it would be practical to provide was utilized, possibly 1,000 horsepower could be developed at all seasons. The topography at the head of the canyon is favorable for the construction of a dam, and a reservoir with a capacity of 5,000 to 10,000 acre-feet could probably be created.

LOWE RIVER.

Lowe River, the largest stream in the district, rises north of Marshall Pass, flows in an easterly direction for about 30 miles, and enters the bay at its southeast corner about 2 miles from Valdez. Its flow is derived largely from glacial sources and is subject to great variation. Excessive floods occur during the summer, whereas in the winter the discharge is said to reach a very low stage, though no measurements have been made later than October 17. About 3 miles below Marshall Pass the river enters Heiden Canyon and is confined between steep walls for 6.5 miles. At the lower end of the canyon, about 1.5 miles above Wortman's, it occupies a broad gravel-filled valley through which it flows in many constantly shifting channels for 4.5 miles to Keystone Canyon. There the mountains close in and for a distance of 3 miles the walls of the canyon are for much of the way of solid rock and at points rise nearly vertically above the stream for a height of several hundred feet. Between Keystone Canyon and the bay, a distance of about 12 miles, the valley is from 1 to 2 miles wide.

Lowe River falls 1,854 feet between Marshall Pass and Port Valdez, a distance of about 26 miles, making an average grade of about 71 feet per mile.

Power could be developed at both Heiden and Keystone canyons. At the latter the head would have to be developed by a dam across the canyon. Such construction might be warranted if the flow was sufficient to operate a plant of large capacity, but during the winter it becomes very low and there is but little opportunity for storage. Lowe River carries immense quantities of sand and gravel during the summer. The feasibility of constructing high dams on rivers of that type is open to question. Such a project would involve the relocation of the Government wagon road, which now follows the right bank of the river through the canyon.

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Heiden Canyon offers perhaps a more favorable opportunity for power development. Water could be diverted near the head of the canyon to a conduit on the north bank and carried along the bench above the canyon for about 6.3 miles. In that way a head of more than 900 feet could be obtained. The drainage area above the canyon is about 30 square miles and ranges in elevation from 1,500 to about 7,000 feet. It lies in an area of heavy snowfall, and the winter temperatures, though modified by the warmer coastal air current, are probably sufficiently low to prevent much surface run-off during that season. So far as is known there is no opportunity for storage. From about the middle of May until October several thousand horsepower could no doubt be developed, but the high elevation of the basin might cause such a small run-off and low temperatures as to render the operation of the plant impracticable during the winter. On October 17, 1913, there was considerable slush ice running in the river at the foot of Heiden Canyon, large masses of anchor ice had formed on the river bottom, and solid ice extended several feet from each edge.

MINERAL CREEK.

Mineral Creek has its source in a glacier at an elevation of about 1,000 feet. It is about 8 miles long and flows southward until about 1 mile from its mouth, when it turns toward the west and enters the bay about 4½ miles west of Valdez. The basin covers an area of 14 square miles. The topographic features are exceedingly rough, including many sharp pinnacles and narrow spurs. Many of the peaks exceed 6,000 feet in altitude and large glaciers occupy the upper parts of the tributary valleys. The main valley is bounded by precipitous slopes on both sides, with a U-shaped cross section. For the first 3 miles the valley is narrow and there are a few solid-rock canyons; below this stretch the river has built up a broad flood plain averaging about one-fourth mile in width. About 1½ miles from the mouth, as the stream leaves the mountains and approaches the tidal flats, a ridge 200 to 300 feet high crosses the valley. The creek has cut its way through this ridge at the east end, forming a narrow rock canyon, where a dam 50 to 60 feet high could easily be constructed.

Brevier Creek heads in a large glacier about a mile west of Mineral Creek and falls more than 1,000 feet in its course. During warm weather it is a torrential stream, but the discharge rapidly decreases on the approach of cold weather, and the bed of the stream near the mouth is said to be dry in the winter, though in its upper course there is a small surface flow.

Glacier Creek enters Mineral Creek just below Brevier Creek, and is similar in character, but its flow is considerably smaller.

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The East Fork of Mineral Creek enters the major stream about 1 mile below Glacier Creek. It is less than 2 miles long and rises in a glacier about 2,000 feet above the level of Mineral Creek. Nearly a thousand-foot fall occurs in the lower half mile of its course. It would probably furnish 200 to 300 horsepower for 4 or 5 months in the summer, and water could be easily diverted to a pressure pipe on the south side of the creek. On October 24 there was about 6 inches of snow, at an elevation of 900 feet above the mouth, and the creek was frozen over solid except where it had a vertical fall of several feet. It is doubtful if it would be feasible to attempt to develop water power on upper Mineral Creek or any of its tributaries between the early part of November and the middle of May. At the lower canyon on Mineral Creek continuous power could no doubt be developed throughout the winter, but a head of not over 75 feet could be obtained. A flow of 37 second-feet, as measured on November 24, 1913, under a head of 75 feet would produce under operating conditions only little more than 200 horsepower, which is several times greater than should be expected later in the winter. The storage obtained would probably be sufficient to equalize the flow during much of the winter, but would be of little value in caring for the accumulation of excess water in the fall.

Placer gold is said to occur in the gravels of Mineral Creek above the lower canyon, which would be flooded by the construction of a dam.

The basin is barren of all timber except a few scattered cottonwoods in the lower valley and alders on the valley sides up to an elevation of about 1,500 feet, where there is sufficient soil to support their growth.

Considerable prospecting for gold quartz is being done each summer in the headwaters of Mineral Creek,[1] and some development work has been accomplished. A small stamp mill for preliminary work was erected in the fall of 1913 at the mouth of Brevier Creek. Power for its operation will be obtained from Glacier Creek when the flow is sufficient. The plant is described on pages 108–109.

In the summer supplies can be hauled up the creek on wagons for about 4 miles, when the stage of the water will permit travel along the bars. Pack animals are used for the remainder of the distance. When the water is high everything has to be packed either from Valdez or from the boat landing near the mouth of the creek. The pack trail crosses the creek at the lower canyon and follows the west side of the valley. There are branch trails leading to the various properties. Most of the hauling is done in the winter when sleds can be used.

[1] See Brooks, A. H., Gold deposits near Valdez: U. S. Geol. Survey Bull. 520, pp. 125–127, 1912.

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GOLD CREEK.

GENERAL FEATURES.

Gold Creek enters Port Valdez about 4 miles below Mineral Creek. It flows southward, is about 3 miles long, and drains an area of 10 square miles. The surrounding ridges are 4,000 to 5,000 feet high. The flow in the summer is maintained largely by glaciers which lie at elevations between 2,300 and 5,000 feet and cover about one-third of the basin. Gold Creek occupies a hanging valley that opens to the bay at an elevation of about 800 feet above and about one-half mile horizontally from tidewater. Through the falls the creek is confined in a sharp rock gorge that rises precipitously to the summit of the mountains on either side. Above the falls the valley widens into a gravel filled basin which is about one-half mile long and 1,000 feet in maximum width. Placer gold is said to occur in the gravel of this basin, and considerable work has been done preparatory to the installation of an hydraulic plant. Above this basin for a distance of about 1 mile the valley is made up of smaller basins separated by rock gorges and contracted sections of the valley, through which the stream has a decidedly increased grade.

There is no timber in the basin except alders and small brush.

Small water power could be developed in the summer at sections above the main falls, where the fall is concentrated for short stretches. In the lower section of the creek a head of over 800 feet could be obtained by a pipe line less than 1 mile long leading to a power house on the beach, where probably a thousand horsepower could be generated for 6 or 7 months in the year. The discharge, however, is subject to wide variation, and from November until May it is doubtful if it would be sufficient to warrant the operation of a plant. The basin receives a heavy snowfall, causing large snowslides which would require costly construction to protect a pipe line. A horse trail leading up the basin along the west side of the valley is dangerous to travel and at times impassable during the fall and spring, when the slides are most active. A dam could be easily constructed at the head of the falls and small storage could be obtained, but ground now claimed for placer mining would thereby be flooded.

Gold quartz prospects have been found near the head of Gold Creek, but very little development work has been done.

GOLD CREEK NEAR VALDEZ.

This station was established September 8, 1913, at the head of the falls on the left bank of the creek at an elevation of about 800 feet above sea level and just below the Budd Mining Co.'s camp. Discharge measurements were made by wading.

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Discharge measurements of Gold Creek near Valdez, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 8		[a] 12.1	Oct. 13	3.03	21
Aug. 10		[b] 202	23	2.95	17.6
Sept. 8	3.19	34	Nov. 24		[a] 6.5

[a] Section one-half mile below gage at mouth of creek.
[b] Section one-half mile above gage at upper end of lower basin.

Daily gage height, in feet, and discharge, in second-feet, of Gold Creek near Valdez, Alaska, for 1913.

[Drainage area, 9.5 square miles. W. R. Van Ornum, observer.]

Day.	Sept.		Oct.		Nov.		Day.	Sept.		Oct.		Nov.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1							16	3.52	94	2.95	17.8		
2							17	3.45	78	2.95	17.8		
3			3.45	78	3.25	42	18	3.38	63	2.91	16.4		
4			3.45	78	3.05	23	19	3.40	67	2.95	17.8		
5			3.45	78	2.95	17.8	20	3.38	63				
6			3.35	58	2.95	17.8	21	3.38	63	2.95	17.8		
7			3.23	39	2.85	14.6	22	3.48	85	2.97	18.4		
8	3.20	35	3.15	30			23	5.70		2.95	17.8		
9	3.22	38	3.15	30	2.75	12.0	24			2.92	16.7		
10	3.15	30	3.13	28			25			2.85	14.6		
11	3.20	35	3.05	23			26			2.85	14.6		
12	3.30	49					27						
13	3.45	78	3.03	21			28	3.80	165	2.80	13.1		
14	3.55	101	3.02	21			29	3.75	152				
15	3.58	108	2.95	17.8			30			2.93	17.0		
							31						

NOTE.—Discharges computed from a rating curve fairly well defined between 15 and 40 second feet.

SHOUP BAY.

GENERAL FEATURES.

Shoup Bay is an arm of Port Valdez near its northwest corner. It is about 2 miles long and varies in width from one-fourth to three-fourths mile. Many of the most important gold quartz veins of the Valdez district occur near Shoup Bay.[1] The entrance to the bay is shallow, but there is a narrow channel that is sufficiently deep for small launches. The main drainage into the bay is from Shoup Glacier, which reaches down to tidewater. It discharges large quantities of silt and has built up a broad mud flat at the head of the bay.

Uno Creek discharges into the bay near the northeast corner. It drains a roughly circular-shaped area comprising 5 square miles east of Gold Creek. Uno Basin occupies the central part of the area and is not as steep sloped as the bounding ridges, which rise sharply,

[1] See Brooks, A. H., op. cit., pp. 123–125.

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reaching a maximum elevation of 5,445 feet on the north. Between Uno Basin and tidewater the creek descends in a series of rapids and falls through a height of 1,000 feet in a horizontal distance of but little over one-half mile. Several hundred horsepower could be developed at the falls from May until October, but after October the flow decreases rapidly, and it is believed that there would be a period of several months in the winter and early spring when it would be too small for practical use.

Estimates of discharge were made at the mouth for part of the summer of 1913. (See table, p. 96.) The minimum discharge measured was 2.5 second-feet on November 20. At that time the creek was frozen solid for much of the way between the foot of the falls and tidewater and the snow was about 3 feet deep. Because of heavy ice and snow the only section where a measurement could be made with reasonable accuracy was just below high-tide level at time of low tide. The actual discharge may have been somewhat greater than measured because of seepage through the beach sands, over which the creek flowed for a short distance above the measuring section.

The flow of Uno Creek is derived almost entirely from rainfall and melting snow. The only glacier in the basin is small, covering an area of only about 60 acres.

McAlister Creek enters Shoup Bay from the west. It drains an area of 2.5 square miles.

There is said to be opportunity to develop water power in the summer from streams flowing to the margin of Shoup Glacier from high mountains to the north.

UNO CREEK AT SHOUP BAY.

This station was established August 5, 1913, on the right bank of the creek about 300 feet from high-tide level and just below the proposed tailrace from the Sea Coast Mining Co.'s water-power plant.

Discharge measurements of Uno Creek at Shoup Bay in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 8	.....	6.3	Oct. 13	2.15	8.1
Aug. 5	3.18	54	23	.....	7.2
10	3.18	61	Nov. 20	.....	2.5
Sept. 7	2.31	14.0			

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Daily gage height, in feet, and discharge, in second-feet, of Uno Creek at Shoup Bay for 1913.

[Drainage area, 5.0 square miles. R. M. Redpath, observer.]

Day.	Aug.		Sept.		Oct.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			2.69	30	2.76	34
2			2.60	26	2.55	24
3			2.55	24	2.45	19.3
4			2.46	19.7	2.50	21
5	3.18	58	2.41	17.7	2.58	25
6	3.28	64	2.38	16.6	2.46	19.7
7	3.22	60	2.32	14.5	2.42	18.1
8	3.44	73	2.30	13.8	2.31	14.2
9	3.38	70	2.30	13.8	2.30	13.8
10	3.18	58	2.26	12.6	2.28	13.2
11	3.15	56	2.27	12.9	2.22	11.4
12	3.00	47	2.38	16.6	2.25	12.3
13	3.02	48	2.94	44	2.15	8.1
14	3.02	48	3.07	51		
15	2.95	44	3.03	49		
16	2.88	40	2.84	38		
17	2.88	40	2.70	30		
18	2.88	40	2.61	26		
19	2.86	39	2.62	27		
20	3.02	48	2.51	22		
21	3.08	52		30		
22	3.02	48	2.82	37		
23	2.97	45	3.55	80		
24	3.00	47	3.62	85		
25	3.00	47	3.09	52		
26		54	2.99	46		
27		62	2.66	29		
28	3.38	70	2.62	27		
29	3.05	50	2.80	36		
30	3.07	51	2.82	37		
31	2.84	38				
Mean discharge		51.7		32.1		18.0
Mean per square mile		10.3		6.42		3.60
Run-off (depth in inches on drainage area)		10.3		7.16		1.74
Accuracy		C.		C.		C.

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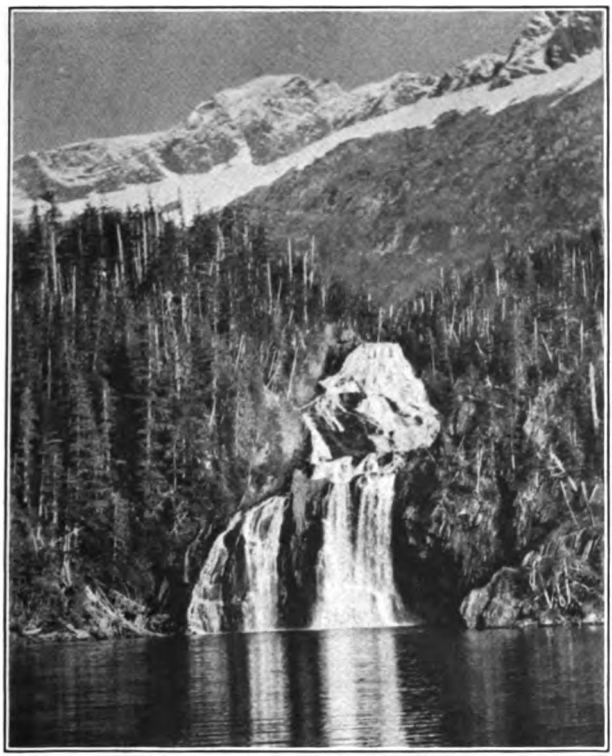

A. OCTOBER 10, 1913.

B. AUGUST 9, 1913.

FALLS AT EAGLEK BAY.

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A. DAVIS LAKE FROM POINT NEAR OUTLET.

B. FALLS ON DAVIS CREEK BELOW LAKE.

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MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in 1913 on streams discharging to Port Valdez are given in the following table:

Miscellaneous measurements on streams tributary to Port Valdez in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. mi.*	*Sec.-ft.*
May 7	Solomon Gulch	Port Valdez	Elevation 550 feet	12.7		
9	do	do	do	16.0		
Nov. 24	do	do	Mouth	[a] 35		
Oct. 17	Lowe River	do	Foot of Heiden Canyon.	92	[b] 50	1.82
24	Mineral Creek	do	Between Brevier and Glacier Creek at elevation 650 feet.	26		
May 10	do	do	At lower canyon, elevation 100 feet.	79	39	2.03
Oct. 24	do	do	do	74	39	1.90
Nov. 24	do	do	do	37	39	.95
Oct. 24	Brevier Creek	Mineral Creek	Elevation 100 feet above mouth.	4.4	4.9	.90
24	Glacier Creek	do	Elevation 150 feet above mouth.	2.0		
24	East fork of Mineral Creek.	do	Elevation 1,000 feet above mouth.	2.6	3.8	.68
May 8	McAlister Creek	Shoup Bay	Mouth	2.4	2.5	.96

[a] Estimated. [b] Approximate.

EAGLEK BAY.

Eaglek Bay lies about 12 miles east of Port Wells, between Esther Passage on the west and Unakwik Inlet on the east. About a mile from the head on the west is a small cove into which flows an unnamed stream that is locally considered to afford one of the important water powers of that section of Prince William Sound. It falls directly into salt water through a height of about 200 feet over a nearly vertical rock bluff. (See Pl. XIII.) About 250 feet from the head of the falls the creek leaves a lake or series of lakes estimated to be 2 to 3 miles long and one-fourth to one-half mile wide. No information is available regarding the extent of the drainage basin or the source of the water. As seen from a point a short distance from the falls, the inflow apparently is mainly derived from the slopes of high mountains east of Davis Creek.

Between the outlet of the lake and the head of the falls—a distance of 200 to 300 feet—the creek is confined between steep walls and falls about 10 feet. A dam could there be constructed with a bottom width of about 100 feet, and it would probably be practicable to raise the level of the lake 50 feet or more. A solid rock foundation could probably be obtained with small expense. Water could be cheaply carried to a power house at sea level by a combination tunnel and pressure pipe or pressure pipe alone.

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Assuming a storage area of 1 square mile a dam 50 feet high would store sufficient water under head of 200 feet to produce about 700 horsepower for 365 days with an efficiency of 70 per cent at the wheel. That would require a continuous discharge of approximately 44 second-feet. The only data available regarding the discharge of the stream are two miscellaneous measurements listed below. With those measurements and a knowledge of the high rate of run-off that occurs throughout Prince William Sound from May until September it seems reasonable to believe that an average flow of considerably more than 44 second-feet could be expected throughout the year.

There is considerable fair-sized timber along the shores and lower slopes adjoining Eaglek Bay.

Miscellaneous measurements.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
Aug. 9	Unnamed	Eaglek Bay	Above falls	656
Oct. 11	do	do	do	38

PORT WELLS DISTRICT.

GENERAL FEATURES.

Port Wells forms the extreme northwest part of Prince William Sound, of which it is the largest fiord. From the head of its northern arm, College Fiord, to the head of its southern arm, Cochrane Bay, the distance is about 50 miles. Harriman Fiord, Bettles Bay, Pigot Bay, Passage Canal, and Blackstone Bay are western arms. The eastern side has a more regular shore line. It is surrounded by a country of bold relief. Most of the tributary valleys are occupied by glaciers. In the larger ones the ice generally extends down to or near tidewater, thus eliminating all opportunity for water-power development. Most of the small streams come from glaciers located in their headwaters. All have a large run-off in the summer, but in the winter their flow undoubtedly becomes very low and offers but small possibility of power development except where it can be supplemented by storing excess flow during the summer and fall.

Gold-lode prospecting is in progress near Port Wells.[1] On some of the properties considerable development work has been done, and it is reported that several small stamp mills are to be installed. The town of Golden (sometimes called Port Wells), on the east side of the fiord 4 miles north of Esther Passage, is the local supply point for the district. A weekly launch service is maintained between Valdez

[1] See Johnson, B. L., The Port Wells gold district: U. S. Geol. Survey Bull. 592, pp. 195-243, 1914.

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and Port Wells and ocean-going vessels occasionally enter the fiord to discharge freight.

The shores are quite generally timbered with spruce up to an elevation of a few hundred feet. Most of it is stunted and scraggy, though there is a limited quantity of good-sized trees that are suitable for saw logs.

This report is based on a hasty reconnaissance of streams entering the central part of the fiord, where prospecting is being carried on most actively.

DAVIS CREEK.

GENERAL FEATURES.

Davis Creek enters Port Wells at the town of Golden. It has its source in a lake at an elevation of about 140 feet above sea level. (See Pl. XIV, *A*, p. 97.) The lake is about half a mile from tidewater and is estimated to be about 2 miles long and one-quarter mile in average width. It is said to be very deep. High mountains rise abruptly from all sides. Many glaciers and large snow banks occupy depressions between the peaks and on the slopes of the mountains. Between the lake and salt water is a broad, open valley, through which the creek flows in a deep box canyon for most of the way. (See Pl. XIV, *B*.) There is an excellent opportunity for the construction of a pipe line to carry water from the lake to a power house on the beach. A dam 25 feet high with a top length of about 150 feet could be constructed near the outlet of the lake. A solid rock foundation could undoubtedly be obtained. A power system could be easily installed on Davis Creek, and for six or seven months each year the flow would probably be ample for a plant of several hundred horsepower, but in the winter the flow probably becomes very small during protracted periods of low temperatures, and at such times would have a capacity of less than one hundred horsepower unless storage was provided.

DAVIS CREEK AT GOLDEN.

A gage was installed on Davis Creek on August 6, 1913, at the foot of the first falls below the lake, at an elevation of about 100 feet above sea level. The channel below the gage is considered permanent. Measurements were made by wading just below the outlet of the lake.

Discharge measurements of Davis Creek at Golden, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 6	5.60	179	Nov. 20	4.48	21
Oct. 9	4.89	46			

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Daily gage height, in feet, and discharge, in second-feet, of Davis Creek at Golden, Alaska, for 1913.

[Alex. Beyer, observer.]

Day.	August.		September.		October.		November.		December.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	5.10	77	.....	.....	4.72	32	3.93	11.6
2	.....	.....	5.10	77	.....	.....	4.92	50	3.91	11.3
3	.....	.....	5.02	63	.....	.....	4.72	32	3.91	11.3
4	.....	.....	4.94	52	.....	.....	4.71	32	3.90	11.2
5	.....	.....	4.89	46	.....	.....	4.95	54	3.89	11.1
6	.....	.....	4.86	43	.....	.....	4.91	48	3.88	11.0
7	5.57	172	4.84	42	.....	.....	4.88	45	3.90	11.2
8	5.94	270	4.82	40	.....	.....	4.81	39	3.88	11.0
9	6.49	437	4.82	40	4.89	46	4.79	37	3.86	10.7
10	5.98	281	4.80	38	.....	41	4.77	36	3.85	10.6
11	5.68	200	5.10	77	4.77	36	4.41	19.1	3.84	10.5
12	5.52	160	5.41	135	4.72	32	4.34	17.6	3.83	10.4
13	5.43	140	5.62	184	4.62	26	4.31	17.0	3.98	12.2
14	5.41	135	5.83	239	4.61	26	4.31	17.0	4.16	14.5
15	5.42	137	5.86	248	4.60	25	4.28	16.5	4.33	17.4
16	5.40	133	6.22	352	4.62	26	4.26	16.1	4.45	20
17	5.44	142	6.10	316	4.63	27	4.33	17.4	4.48	21
18	5.41	135	5.40	133	5.16	88	4.46	20	4.50	22
19	5.30	113	5.80	231	6.20	346	.....	20	4.67	29
20	5.32	117	5.62	184	5.68	200	4.48	21	4.71	32
21	5.40	133	5.38	129	5.10	77	4.73	21	4.73	33
22	5.48	151	.....	396	5.78	226	4.66	20	4.71	32
23	5.50	155	7.20	664	5.67	197	4.48	19	4.64	28
24	5.46	146	.....	.....	5.20	95	4.46	18	4.49	21
25	5.62	184	.....	.....	5.04	67	4.45	17	4.48	21
26	5.84	242	.....	.....	4.91	48	4.41	16	4.47	21
27	6.70	504	.....	.....	4.88	45	4.40	15	4.45	20
28	6.43	418	.....	.....	4.86	43	4.39	14	4.43	19.6
29	5.64	189	.....	.....	4.83	41	4.37	13	4.41	19.1
30	5.46	146	.....	.....	4.48	21	4.36	12	4.39	18.6
31	5.30	113	.....	.....	4.33	17.4	.....	.....	4.38	18.4
Mean	.....	198	.....	165	.....	78.1	.....	25.1	.....	17.8
Accuracy	.....	C.	.....	C.	.....	C.	.....	C.	.....	D.

NOTE.—Gage heights affected by ice from Nov. 21 to 30. Discharges for that period interpolated. Rating curve fairly well defined between 20 and 200 second-feet.

AVERY RIVER.

GENERAL FEATURES.

Avery River is a tributary to Port Wells about 2 miles north of the town of Golden. It drains an area of rugged relief similar to though somewhat larger than that of Davis Creek. The main stream forms in a large glacial cirque, from which it emerges at an elevation of about 100 feet above sea level. A small, shallow lake at the base of the cirque covers an area of 5 or 6 acres. The distance from the outlet of the cirque to tidewater is about one-half mile. At its mouth Avery River has a nearly vertical drop of about 60 feet, falling directly into salt water at high tide. (See Pl. XV, *B*.)

Power could be developed on Avery River either by utilizing the entire fall of 100 feet by carrying the water in a pipe from the outlet of the cirque to a power house located at any convenient point on the

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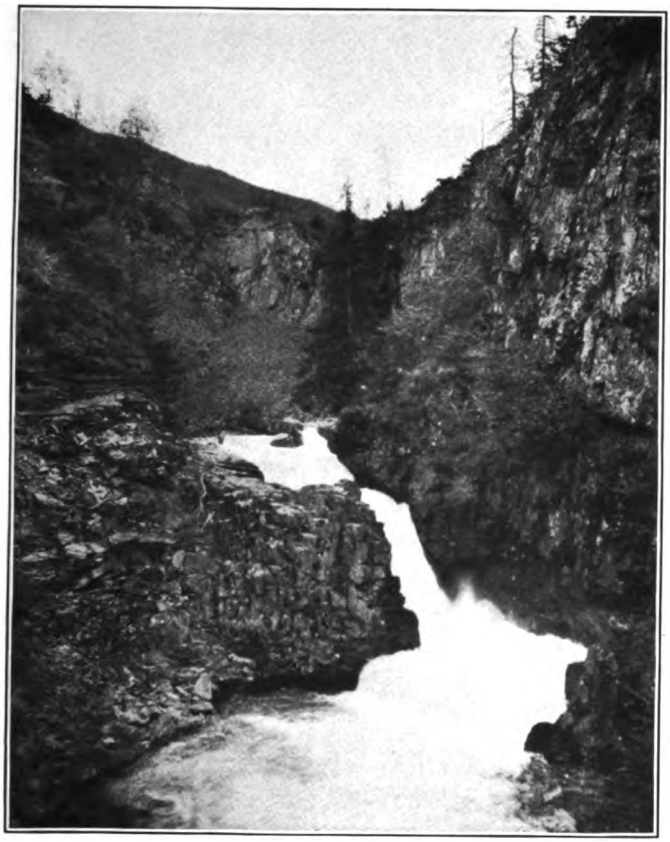
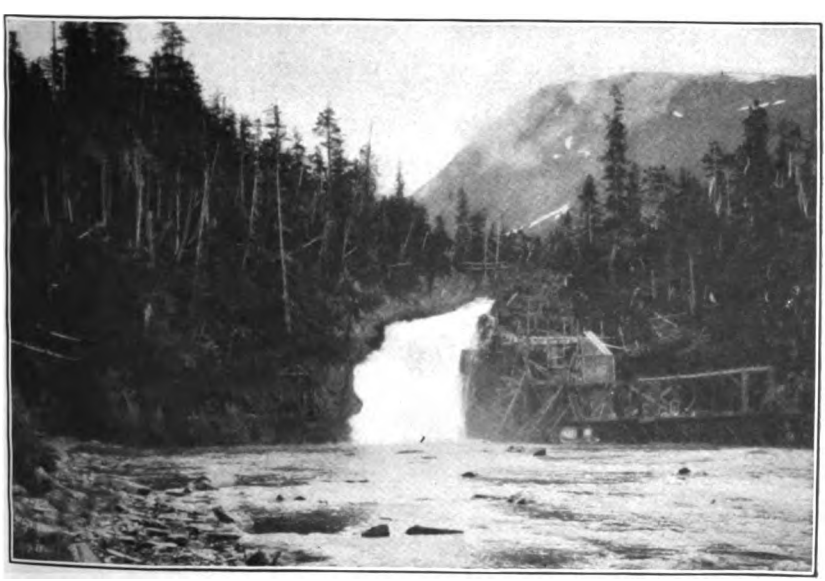


A. FALLS ON BENCH CREEK.



B. FALLS ON AVERY RIVER.

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beach, or by building a power house at the foot of the falls and leading the water directly from the head of the falls through the turbines. The latter method would be cheaper, because it would not require so long a pipe line as the former. The particular type of plant that would be best suited for the needs would depend on the amount of power required.

Considerably more power could undoubtedly be developed by utilizing the entire head, though the increase in power would not be in direct proportion to the difference in head, since the discharge would be somewhat greater at the lower intake, and the friction head lost in the pipe line would tend to slightly decrease the advantage of the higher head. A dam 30 to 40 feet high could be constructed at the outlet of the cirque, with a top length of about 300 feet. Considerable storage would thereby be obtained. Several feet increase in head could be obtained by constructing a dam across the canyon at the head of the falls. A small sawmill was erected in the summer of 1913 at the foot of the falls, and was operated by an overshot water wheel.

The minimum flow during the period covered by the records below was 44 second-feet on November 26. With an efficiency of 70 per cent at the wheel, that discharge could produce about 350 horsepower, using the entire head of 100 feet, and a little over 200 horsepower at the lower falls under a head of 60 feet. Sufficient storage might be provided to assure that amount of power throughout the winter, but without storage it would probably be less than half that quantity at minimum flow.

AVERY RIVER NEAR GOLDEN.

A gage was installed on Avery River on August 7, 1913, on the right bank of the creek, about 300 feet above the falls. Low-water measurements were made by wading above the falls. At high stages they were made below the falls from a boat when the tide was low and the river had an unobstructed flow.

Discharge measurements of Avery River near Golden, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 7	4.98	198	Oct. 10	4.27	57

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Daily gage height, in feet, and discharge, in second-feet, of Avery River near Golden, Alaska, for 1913.

[John Rueff, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
1	.....	.....	4.68	129	5.20	255	5.00	204
2	.....	.....	4.50	93	4.96	194	6.20	[a] 535
3	.....	.....	4.42	79	4.78	151	4.82	160
4	.....	.....	4.36	70	4.76	146	4.50	93
5	.....	.....	4.30	61	4.74	142	4.44	83
6	.....	.....	4.32	64	4.56	104	4.34	67
7	4.98	199	4.32	64	4.50	93	4.28	58
8	5.78	415	4.30	61	4.38	73	4.26	56
9	5.50	337	4.30	61	4.32	64	4.24	53
10	5.20	255	4.28	58	4.28	58	4.20	48
11	5.10	229	4.26	56	4.26	56	4.22	51
12	4.96	194	4.30	61	4.19	47	4.30	61
13	4.98	199	4.54	101	4.16	44	4.26	56
14	4.98	199	5.00	204	4.16	44	4.24	53
15	4.98	199	5.70	393	4.16	44	4.20	48
16	4.94	189	5.20	255	4.14	42	4.20	48
17	4.98	199	4.88	174	4.10	38	4.19	47
18	4.98	199	4.78	151	4.08	36	4.18	46
19	4.96	194	5.22	260	6.04	[a] 489	4.18	46
20	4.98	199	4.96	194	4.54	101	4.18	46
21	5.40	309	4.70	133	4.64	120	4.20	48
22	5.20	255	5.42	315	5.26	271	4.18	46
23	5.10	229	[a] 7.80	[a] 999	4.60	112	4.18	46
24	5.80	421	7.50	[a] 912	4.56	104	.....	45
25	5.60	365	6.50	[a] 622	4.38	73	.....	44
26	5.10	229	5.62	371	4.28	58	4.16	44
27	6.92	[a] 744	5.10	229	4.26	56	4.18	46
28	5.42	315	5.18	250	4.20	48	4.28	58
29	5.00	204	5.62	371	4.38	73	4.24	53
30	4.90	179	6.60	651	6.04	[a] 489	4.20	48
31	4.70	133	.....	.....	5.08	224	.....	.....
Mean		264		248		124		77.9
Accuracy		D.		C.		C.		C.

[a] Approximate.

NOTE.—Discharge computed from a rating curve that was based on two measurements and is fairly well defined between 50 and 225 second-feet.

HARRISON LAGOON.

Harrison Lagoon is a small westward projection from Port Wells near the southwest corner of Barry Arm. The only tributary stream of consequence is Lagoon Creek, which enters near the northeast corner. It heads in a circular-shaped lake estimated to be about one-quarter mile in diameter. From the lake to sea level the creek falls more than 300 feet in a distance of 1½ to 2 miles. Above the lake the mountains are high and steep. Between the lake and the lagoon is a broad valley through which the stream flows in a succession of falls, rapids, and stretches of moderate grade, keeping close to the foothills on the north. In the last 500 feet of its course the creek falls nearly 100 feet. There is considerable timber on the valley sides, but open, meadow-like expanses cover much of the lower levels.

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The level of the lake could be raised about 10 feet by a dam about 50 feet long at the base and 200 feet at the top. The topography affords a fair opportunity for the construction of a pipe line to the lagoon. Sufficient power could probably be developed in the summer to supply any ordinary mining needs that are liable to arise in the immediate vicinity. In the winter the run-off undoubtedly becomes very low and the storage that could be obtained would only be sufficient to equalize the flow over short periods of time. A flow of 9.0 second-feet as measured at the outlet of the lake on November 20 under a head of 300 feet, would develop about 215 horsepower with an efficiency of 70 per cent. The discharge at the mouth of the creek is increased considerably over that at the lake outlet by numerous small channels from the side slopes.

The result of a miscellaneous measurement made on the creek in 1913 is given in the table on page 105.

HOBO BAY AND CREEK.

GENERAL FEATURES.

Hobo Bay is a small indentation from the west side of Port Wells between Harrison Lagoon on the north and Bettles Bay on the south. Hobo Creek rises in the divide east of Harriman Fiord, and flows southeast with a total length of about 2½ miles, entering Hobo Bay at the head. It is reported that its main source of supply is from glaciers and large snow banks near the head and that the stream drops rapidly as it leaves the mountains. Most of its course is through a broad valley with a moderate grade. The lower end of the valley is contracted by a spur from the south, through which the creek has cut a canyon in the rock. A dam could there be constructed with a height of 50 or 60 feet and a small storage would thereby be provided.

The discharge on November 17 was 19.2 second-feet. That discharge, under a head of 50 feet, would produce only about 76 horsepower with an efficiency of 70 per cent. From the above date until the following May the flow would be considerably less for most of the time.

HOBO CREEK NEAR GOLDEN.

This station was established August 8, 1913, on the right bank of the creek just above high-tide level.

Discharge measurements of Hobo Creek near Golden in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 8	4.51	87	Nov. 19	3.79	19.2
Oct. 10	3.98	24			

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Daily gage height, in feet, and discharge, in second-feet, of Hobo Creek near Golden for 1913.

[Cris. Everson, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			4.17	44				
2								
3								
4								
5								
6								
7								
8	4.51	88						
9	4.65	110						
10	4.55	94			3.98	24		
11	4.41	72						
12	4.40	71						
13	4.35	64						
14	4.33	62						
15	4.28	56						
16	4.30	58						
17	4.28	56						
18	4.22	49						
19	4.20	47					3.79	19.2
20	4.24	51						
21	4.25	52						
22	4.26	54						
23	4.25	52						
24	4.25	52						
25	4.25	52						
26	4.30	58						
27	4.70	119						
28	4.61	104						
29	4.60	102						
30	4.52	89						
31	4.19	46						
Mean		69.1						
Accuracy		C.						

HUMMER BAY.

Hummer Bay is situated about 2 miles south of Bettles Bay. Two fair-sized streams enter the bay at the head. The northern one is called Hummer Creek; the one to the south is unnamed. They were not visited except at the mouth, but prospectors living near stated that there were no natural power sites on either stream. They both flow through a broad silt-floored valley before entering the bay. At the time of the writer's visit, on August 8, 1913, each showed a high run-off, due to heavy rains and rapid melting of snow and glaciers in the headwaters. They are said to get very low in the fall and winter and at times go dry at their mouths, the small flow then passing through the porous sands beneath the stream bed.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in 1913 on streams tributary to Port Wells are given in the following table:

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Miscellaneous measurements near Port Wells in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
Aug. 8	Lagoon Creek	Harrison Lagoon	Lake outlet elevation, 300 ft.	83
Nov. 20	do	do	do	9.0
Aug. 8	Hummer Creek	Hummer Bay	Mouth	[a] 240
8	Unnamed	do [b]	do	[a] 160

[a] High run-off due to heavy rains and rapid melting of snow and glacier ice in headwaters. These streams are said to go dry at their mouths in the winter.
[b] This stream enters Hummer Bay at the head south of Hummer Creek.

DEVELOPED WATER POWER.

GENERAL CONDITIONS.

The water powers of Prince William Sound remain practically undeveloped. Cordova and Valdez are the only settlements of sufficient size to justify the installation of plants for lighting. Mining has not yet reached the stage where a sufficient future is assured to warrant the construction of expensive hydroelectric plants. Several plants have been installed for mining, but they are of small capacity, cheap, and temporary in construction, well suited for the needs of a property during the development stage, or for a small mine where interruption in service is not serious and a small amount of ore is available.

CORDOVA.

Light and power for Cordova are furnished by the Cordova Power Co. The plant, which is on the east shore of Orca Inlet about 5 miles north of Cordova, was built in the winter of 1908–9 and first put in operation the following June, and except for short periods it has been in operation continuously since that date. A steam plant is used as auxiliary when the water supply is insufficient. From about the 1st of May until the 1st of December there is said to be ample water to supply the present demands for energy, but for the remainder of the year the steam plant is likely to be required at any time.

Water is diverted from Humpback Creek by a rock-filled timber-crib dam to a 30-inch continuous wood-stave pipe leading to the power house, a distance of about 1,350 feet, where a maximum gross head of 156 feet is obtained. The dam is 45 feet high, 86 feet long at the bottom, and 111 feet at the crest, and is 79 feet wide at the bottom, tapering to a width of 10 feet at the top. This type of construction was adopted because there was plenty of rock and timber handy to the dam site. The entrance to the pipe line is placed near the base of the dam, and is provided with suitable headgate and tapered connections. Trouble is sometimes caused by sand and gravel being brought down during high water and blocking the inlet screens.

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The water wheel is a 43-inch Pelton, designed to develop a maximum of 200 horsepower under an effective head of 148 feet. It is provided with double nozzle. The upper vent is regulated with a hand-operated needle. The lower one has a plain, open-type discharge, and during the winter it will permit the passage of ice particles that might clog a needle nozzle. Directly connected with the wheel is a 125-kilowatt 2,300-volt 3-phase 60-cycle generator. The excitor is a 9-kilowatt 125-volt machine. A Pelton oil-pressure governor in connection with a hood deflector is used to regulate the speed. Current is stepped up to 11,000 volts for transmission to Cordova. The line follows along the steep hillside a few hundred feet above sea level. Snowslides sometimes cause serious damage at certain points along the line, and falling timber is a source of considerable trouble during wind storms. The steam equipment consists of two 150-horsepower boilers and a 250-horsepower compound engine. Crude oil is used for fuel. A 1,600-barrel tank is provided for storage. The steam plant is used during low-water periods while the reservoir is filling. It is seldom operated more than 4 or 5 hours continuously.

Water power is also developed for the operation of a sawmill situated near the ocean dock. Water is collected in a small reservoir created by a timber dam across a small gulch back of the mill. This supply is augmented by a system of contour ditches which collect the water along the hillside and lead it to the reservoir. A head of about 170 feet is obtained at the mill by carrying the water through 1,800 feet of pipe consisting of 450 feet of 14-inch riveted steel, 450 feet of 15-inch riveted steel, and 900 feet of 18-inch continuous wood-stave pipe. The mill is operated by a 48-inch Tutthill wheel and a 48-inch Pelton wheel with rated capacities of 90 and 60 horsepower, respectively, directly connected to the various machines and log hauls. An 18-inch Tutthill wheel is used to drive several small machines and a 5-kilowatt, 125-volt direct current generator, which furnished electricity for lighting.

ORCA.

The Northwestern Fishing Co. has installed one 36-inch and two 16-inch Pelton water wheels at its cannery at Orca. Water is diverted from a small gulch back of the cannery and carried through 700 feet of 8-inch riveted steel pipe to the wheels, where a head of about 240 feet is obtained. The flow of the stream is sufficient for the operation of the wheels only when the run-off is above the average, owing to rains or melting snow. Water power is supplementary to steam power. Large volumes of steam are required in connection with the canning processes. The company has installed two 150-horsepower boilers, also three 15-horsepower upright steam engines, one 15-horsepower gasoline engine, and a 7.5-kilowatt direct-current generator.

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LANDLOCKED BAY.

The Chisna Consolidated Mines Co. installed a small plant on the beach at the mouth of its tunnel several years ago. Water is obtained from Chisna Creek under a head of about 50 feet. Two small Pelton wheels were used to operate a small sawmill, dynamo, and hoist. The plant was nearly in ruins in the summer of 1913 and evidently had not been operated for some time.

GALENA BAY.

The plant of the Galena Bay Mining Co. is on Bottle Creek about 1½ miles from the bay. A rock-filled timber-crib dam 25 feet high crosses the creek at the head of a rock gorge. The power house is situated at the base of the dam and contains a 150-horsepower Francis turbine and a 90-kilowatt dynamo. The fall between the the crest of the dam and the base of the draft tubes is about 48 feet. The electricity has been used for lighting and to operate an air compressor at the mine. The plant has not been in operation for several years. It is said that the water supply was inadequate much of the time during the winter months. Measurements of stream flow on Bottle Creek are published on page 84 of this report.

PORT VALDEZ.

SOLOMON GULCH.

Two water-power plants have been installed on Solomon Gulch. The lower plant is on the beach at the mouth of the creek. This plant was constructed about 1904, and until July 1, 1913, was operated under lease. The lease was held by the Alaska Water, Light & Telephone Co. after June, 1907. The essential equipment consisted of a 150-kilowatt generator operated by a Pelton water wheel. Water was diverted from Solomon Gulch about one-half mile from the power house at an elevation of about 400 feet, and carried in a 2 by 3 foot flume for about one-fourth mile to a point on the ridge facing the bay, where it was conducted through a riveted steel pipe to the power house below. The pipe is 18 inches in diameter at the upper end and 12 inches at the power house. About 1,500 feet above the intake, at the head of the rapids, a dam 14 feet high was built to create storage to carry the daily peak load during low-water periods. The energy was transmitted to Valdez for use for lighting and power.

The company has an auxiliary steam plant at Valdez that is used in case of an interruption in the hydroelectric service. It is also available as an auxiliary power at times of low water. It is understood that the water supply even at times of minimum flow in the winter is ordinarily sufficient to furnish all the power that is demanded of the system.

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In the spring and summer of 1913 the Alaska Water, Light & Telephone Co. built what is now sometimes known as the "upper plant." The power house, which is situated just above the intake of the lower plant, is a 1½-story wood building, 25 by 45 feet in dimensions. Water is diverted through the base of the storage dam, 1,500 feet above, and carried in a continuous wood-stave pipe made up of 500 feet of 36-inch, 500 feet of 33-inch, and 500 feet of 30-inch, to a 26-inch special Francis turbine rated at a normal capacity of 375 horsepower, with a maximum capacity of 500 horsepower. An effective head of about 140 feet is obtained. The generator is an alterating current, 60-cycle, 2,300-volt machine with a rated capacity of 150 kilowatts. Provisions were made for the installation of a second unit like the above if the demand for power should exceed the initial installation.

The dam was raised to a height of 22 feet to increase the storage for use at times of low run-off in the winter. It is constructed of concrete. Sand and gravel were obtained from the creek bed above the dam site. Suitable switchboards are provided at the power house and a set of transformers raises the current to 6,600 volts for transmission. The line is a two-phase system carried on wooden poles, and extends from the power house to Valdez, a distance of about 4½ miles. Across the tide flats at the head of the bay the poles were driven with a pile driver to a depth of 8 to 10 feet, at high tide. That was done to give them extra security against the action of Lowe River and other glacial streams that are continual sources of trouble.

In the fall of 1913 the Valdez Electric Co. was organized to operate the old plant in competition with the one recently installed. A transmission line was built to Valdez and the old water wheel was replaced by one of more modern type. Exact information is not available concerning the operation of this plant, but it is understood that electricity was first transmitted to Valdez about December 1, 1913.

Measurements of the discharge of Solomon Gulch are listed on page 97.

GLACIER CREEK.

A stamp mill was erected on Mineral Creek near the mouth of Glacier Creek in the summer of 1913. A 36-inch Pelton water wheel was directly connected to the main shaft to furnish power. Water for the operation of the wheel will be obtained from Glacier Creek, at an elevation sufficient to give a head of about 170 feet. The conduit consists of 200 feet of 10-inch by 12½-inch board flume, and 600 feet of steel pipe tapering from a diameter of 10 inches at the pressure box to 3 inches at the power house.

The mill was built by the owners of the Mountain King mine. It has two 1,200-pound stamps. The mine was closed about the

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time the mill was completed, so that the plant was not put in operation in the fall of 1913. It was planned to commence operation in the spring of 1914.

For stream-flow data, see page 97.

UNO CREEK.

The Sea Coast Mining Co. began the installation of an hydroelectric plant at the mouth of Uno Creek in 1913. A power house of wood construction was built and a right of way was cleared of brush and prepared for laying a riveted steel pipe line. It is proposed to divert the water from Uno Creek by a low, inexpensive dam at an elevation of 321 feet above the wheel shaft. The plans contemplate the installation of a 290-horsepower Francis-Pelton turbine and an alternating current generator of suitable capacity. A part of the energy will be used to operate a small stamp mill that the power company plans to erect. The excess power will be offered for sale to other mines in the vicinity of Shoup Bay that may need power.

Data regarding the flow of Uno Creek are published on pages 95–96 of this report.

WATER-POWER SITES.

The water-power sites of Prince William Sound are as a rule small but widely distributed. The northern part of the sound from Cordova to Port Wells was examined in some detail. In that section there is hardly a bay or inlet but what has one or more tributary streams on which small water powers could be developed for 6 or 8 months during the year. During the months of low-water flow—from January to April—most of the streams reach a very low stage. There are but few streams on which more than two or three hundred horsepower could be developed at minimum flow, and it is doubtful if there is a single stream on which a plant of more than 1,000 horsepower could be operated continuously without storage. There are, however, numerous sites where small to medium-sized reservoirs could be created, and thus many of the streams made to yield at least a small output throughout the year.

One of the most favorable sites for storage is at Silver Lake on Duck River, near Galena Bay. Nearly the entire run-off could probably be controlled by a dam at the outlet, and a uniform output of 4,000 horsepower or more obtained throughout the year. Some other favorable power sites, though affording less storage than Silver Lake, are Power Creek near Cordova, Solomon Gulch near Valdez, an unnamed stream entering Eaglek Bay, and Davis Creek and Avery River tributary to Port Wells. Detail descriptions of the various sites are published on preceding pages.

There is reported to be a power site on Latouche Island. The Beatson Copper Co. has obtained a permit from the Forest Service

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and is making preliminary investigations. The project involves the diversion of the water of several creeks through pipe lines into a reservoir formed by damming a small lake. From this reservoir the water is to be conducted to the wheels by a pipe line 4,200 feet in length.

In the western part of the sound south of Port Wells there are said to be several good water powers, but no data are available regarding their size or accessibility.

The transmission of electricity is one of the most serious difficulties that will be encountered in utilizing the water powers. Steep rocky mountain slopes, dense growths of bush and trees, heavy snowfall and snowslides, glaciers and broken shore lines are some of the obstacles to be overcome. Unless a market can be created for the power within a short distance of its source it is doubtful if it will ever become of much value. There are, however, good harbor facilities in nearly all parts of the sound, so that ocean-going boats can be anchored within easy transmission distances from the powers. Submarine cable is now being manufactured that will carry electric current up to a pressure of over 20,000 volts. Considerable cable with a capacity of 200 to 300 amperes for 11,000 volts working pressure has been used. Such cable, though expensive, might be practicable for use in crossing narrow bays and inlets where long land lines would be required to carry it around them, or to reach from island to mainland, or from island to island. It might also be of service in crossing glaciers where an overhead line would be very expensive to maintain.

The manufacture of wood pulp should offer a particularly suitable use for the water powers because of the fact that both the timber and the power sites are near tidewater. It is claimed that pulp logs can be towed a distance of 150 to 200 miles at a permissible cost, thus eliminating the necessity of transmitting electricity for long distances to the mills. Any one water power in Prince William Sound would, under such conditions, be within reach of the entire timber supply.

KENAI PENINSULA.

GENERAL FEATURES.

Kenai Peninsula projects from the Alaska mainland in the north-central portion of the Gulf of Alaska. It has an area of approximately 9,000 square miles, most of which lies between meridians 148° and 152° west longitude and parallels 59° and 61° north latitude. The peninsula is bounded by Prince William Sound on the east, the Pacific Ocean on the south, and Cook Inlet on the west. On the north it is joined to the mainland by a strip about 12 miles wide, which separates Portage Bay and Turnagain Arm. These bodies of water are arms of Prince William Sound and Cook Inlet, respectively. Kenai Peninsula has a shore line more than a thousand miles long.

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The surface of the peninsula presents two widely differing physiographic features. About three-fourths of its area, lying in the eastern, central, and southern parts, is characterized by high rugged mountains, 5,000 to 7,000 feet in elevation, which are known as the Kenai Mountains, and by valleys deeply cut by the action of the former ice sheet that covered the area, and remnants of which are still found in the higher portions of the peninsula. The remaining fourth consists of a broad lowland, about 25 miles wide, which slopes from an elevation of about 1,800 feet on the south near Kackemak Bay to an elevation of about 50 feet on the north.

The Kenai Mountains divide lies close to the eastern and southeastern side of the peninsula so that the drainage is principally toward the west and north and the streams flowing into the Pacific and Prince William Sound are short. The largest of the latter is Resurrection River, which is about 25 miles long. It drains an area southwest of Kenai Lake and flows through a wide gravel-floored valley into the head of Resurrection Bay. Kenai River, the largest stream on the peninsula, drains its entire central portion and discharges into Cook Inlet at Kenai. Its drainage area includes two large lakes, Skilak and Kenai, and numerous smaller lakes on its upper tributaries. Kasilof River drains Tustumena Lake and enters Cook Inlet a short distance south of Kenai. Tustumena Lake is about 22 miles long and 6 miles in average width. It is fed by several streams, some of which have their sources in the large glaciers in the Kenai Mountains. Two small streams, Chickaloon and Big Indian rivers, drain a part of the Kenai lowland and discharge into Chickaloon Bay near the west end of Turnagain Arm. The principal streams entering Turnagain Arm from the mountainous area of the peninsula are Resurrection and Sixmile creeks and Placer River.

The fact that steep gradients and waterfalls are identified with streams draining areas of rugged mountainous relief make it obvious that the eastern portion of the peninsula would afford much more favorable opportunities for water-power development than the western portion. Moreover, gold mining, which is the most important industry of the peninsula and which at this time presents the most promising market for water power, is confined to the mountainous area. The investigation of the water supply of the peninsula was carried on only in its eastern portion.

MINERAL RESOURCES.[1]

Gold-bearing lodes have been discovered at many points in the eastern part of Kenai Peninsula, and at the present time form the principal mineral resource of that region. The most important lodes

[1] The mineral resources of Kenai Peninsula are fully treated in Bulletin 587 of the U. S. Geological Survey, Geology and mineral resources of Kenai Peninsula, Alaska, by G. C. Martin, U. S. Grant, and B. L. Johnson, published in 1915.

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are those near Falls Creek, Porcupine Creek, and Moose Pass. Gold quartz veins also occur at several localities between Kenai Lake and Seward. The veins so far discovered are all small. Four or five stamp mills of small capacity have been installed and several similar installations are contemplated. Gold placers have been worked quite extensively on Sixmile River and Resurrection Creek and their tributaries, also on Cooper and Quartz creeks. Most of the richest deposits are now worked out, and the future of placer mining on the peninsula depends almost entirely on whether the low-grade deposits which are practically unexploited can be made to yield a profit.

Considerable bodies of lignitic coal occur in the western part of the peninsula. In any comprehensive study of the power resources of this region those beds would be worthy of consideration.

The Matanuska coal field,[1] containing areas of workable high-grade coal, lies about 65 miles northeast of Turnagain Arm, and the future development of this field is a further factor to be considered in planning extensive hydroelectric installation in Kenai Peninsula.

TIMBER.

Kenai Peninsula is quite heavily timbered in most of its valleys up to elevations of 1,200 to 1,500 feet above sea level. Spruce is the most plentiful variety and the most valuable for commercial uses, but hemlock is found in some localities, and also poplar, birch, cottonwood, willow, and alders. The alders cover the mountain slopes with dense and often almost impenetrable thickets to elevations considerably above the limit of the spruces. A luxuriant growth of wild hay can be found extending well up into the timberless area, but nearer the summits the mountain sides become craggy and rock strewn and support only a limited moss growth.

Except for a strip across the southeastern side, the peninsula lies entirely within the Chugach National Forest. This does not mean that the timber supply is generally distributed over the area because, in fact, the really valuable timber is restricted to a few localities. Immense tracts have been destroyed by the ravages of forest fires, which originated from careless campers or accidental causes. The country is too sparsely populated for dealing with these fires promptly and in an effective way, and once started they can quickly reduce an area covered by timber and moss which it has taken centuries to produce to a waste strewn and tangled with dead and falling trees. The officials of the forest reserve have made energetic efforts to cope with these fires, but too often their handicap is so great as to make their efforts ineffectual. The officials of the Chugach National Forest also have jurisdiction over the development of water power within its boundaries.

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.

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MAP O

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The local spruce lumber was used to some extent in the structures of the Alaska Northern Railway, which has been built across the peninsula, for, although it did not show as great strength as the timber from the States, in many places its use at about $25 per thousand feet was found to be more economical than the latter at $35 to $40 per thousand. Near most of the mining camps there is sufficient timber of a quality satisfactory for mining structures. The quantity of timber which will square greater than 12 inches is very small. All demands for better grades of lumber are supplied from Seattle. The supply of timber suitable for fuel is plentiful, and with labor costing $3 to $4 per day with board cord wood can be procured at quite a reasonable figure.

GAGING STATIONS AND MEASURING POINTS.

The points at which gaging stations were maintained or discharge measurements made on streams in Kenai Peninsula in 1913 are shown by the following list. The numbers correspond to those given on Plate XVI.

1. Lowell Creek above pipe intake.
2. Lowell Creek at mouth.
3. **Kenai Lake at Roosevelt.**
4. **Kenai River at Kenai Dredging Co.'s camp.**
5. Ptarmigan Creek at lake outlet.
6. Ptarmigan Creek at mouth.
7. Falls Creek at intake of Skeen-Lechner ditch.
8. **Falls Creek at railroad crossing.**
9. Grant Creek at mouth.
10. **Quartz Creek at Fairman's Cabin.**
11. Lost Creek 3 miles below lake outlet.
12. Juneau Creek at mouth.
13. Stetson Creek at mouth.
14. Cooper Creek above Stetson Creek.
15. Cooper Creek at mouth.
16. Russian River ¼ mile below lower lake outlet.
17. **Russian River at mouth.**
18. Canyon Creek above Mills Creek.
19. **Sixmile Creek at Sunrise.**
20. **Mills Creek 2 miles above mouth.**
21. Juneau Creek above upper ditch intake.
22. Resurrection Creek above Gold Gulch.

NOTE.—Black-faced type indicates regular gaging stations; light-faced type points of miscellaneous measurements.

LOWELL CREEK.

Lowell Creek is one of the short streams that drain the eastern slope of the Kenai Mountains. It heads in a high glacier west of the town of Seward, and in its course of approximately 5 miles drops with a very steep gradient to its mouth near the head of Resurrection

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Bay. (See Pl. XVII, *A*.) It depends for its summer flow principally on the melting of the snow banks and glaciers; in winter its flow is maintained by the occasional thaws and rains. Lowell Creek supplies water for the operation of the hydroelectric plant of the Seward Light & Power Co., which is described on pages 131–133.

Two discharge measurements were made above the pipe intake of this plant and one at the mouth below the return water from the wheel. The last shows a large loss by seepage as the creek passes over the coarse gravel fan which it has deposited as it emerges from its narrow valley.

Discharge measurements of Lowell Creek in 1913.

Date.	Point of measurement.	Discharge.	Date.	Point of measurement.	Discharge.
		Sec.-ft.			*Sec.-ft.*
Aug. 15	Above pipe intake	58	Oct. 28	At mouth	9.3
Oct. 28	do	18.8			

TONSINA CREEK.

Power development has been contemplated on Tonsina Creek, which is the next stream south of Lowell Creek and enters Resurrection Bay about 3 miles south of Seward. The creek is similar in character to Lowell Creek but drains a smaller area. Observation has shown the winter flow to be small and undependable, and the project was consequently abandoned.

RESURRECTION RIVER.

The largest of the streams flowing from the eastern slope of the Kenai Mountains is Resurrection River, whose drainage area lies southwest of Kenai Lake. It is about 25 miles long and its mouth is at the head of Resurrection Bay, about 2 miles from Seward.

Resurrection River is a typical glacial stream, wild and unruly in times of flood, but decreasing to a rivulet in prolonged periods of low temperature. In its lower part it flows through a flat gravel valley, and in many places splits into several channels. (See Pl. XVII, *B*.) The fall in this section is 25 feet to a mile. A scheme to develop power by diverting water in a canal for 3 or 4 miles and utilizing the head thus gained has been abandoned as impracticable.

KENAI RIVER DRAINAGE BASIN.

GENERAL FEATURES.

Kenai River drains an area about 90 miles long in an east-west direction and 20 miles in average width. From its mouth on Cook Inlet it stretches nearly across the central part of the peninsula to the head of

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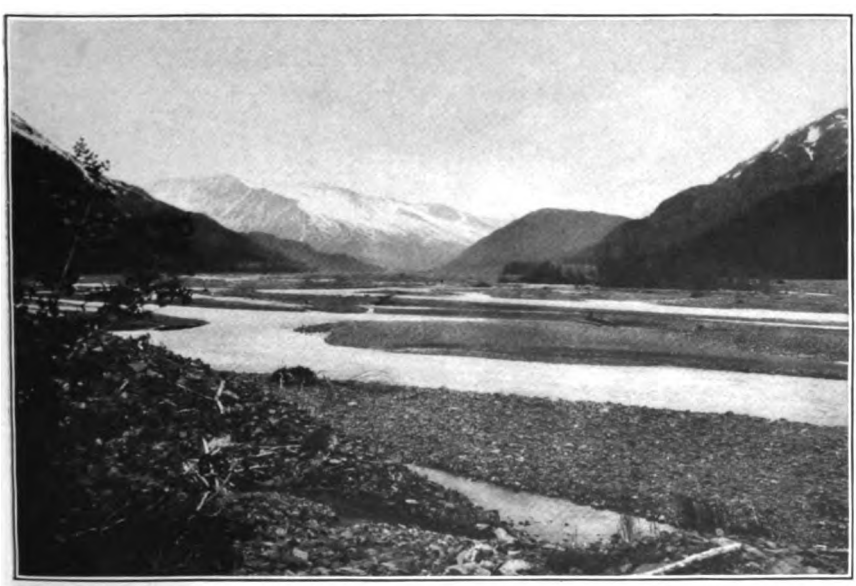
A. LOWELL CREEK AT PIPE INTAKE.



B. RESURRECTION RIVER, LOOKING UPSTREAM.

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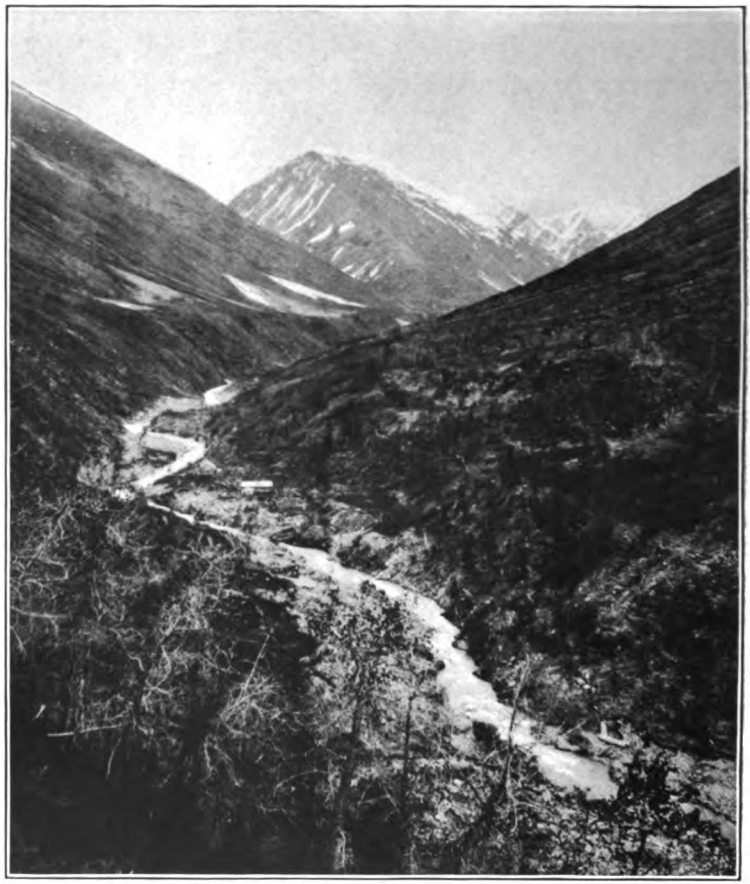
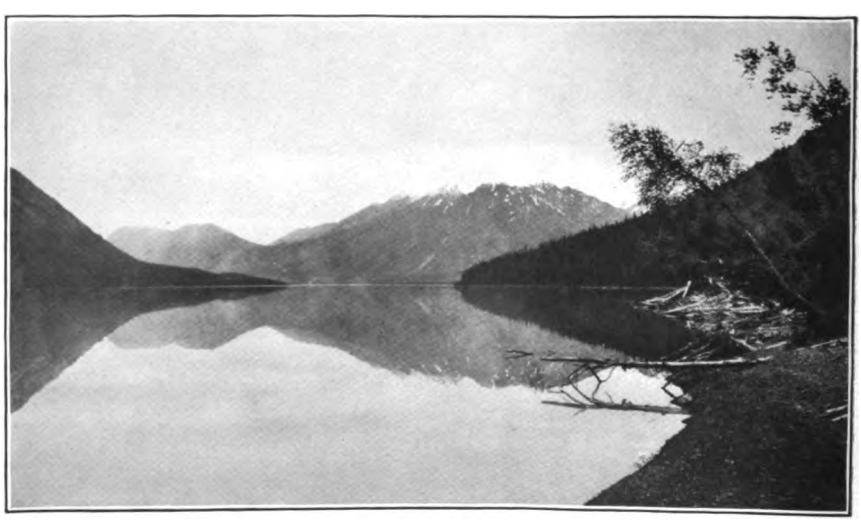


A. UPPER VALLEY OF MILLS CREEK.



B. WEST END OF KENAI LAKE.

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Snow River, its most remote tributary. Snow River rises in the glaciers of the mountains bordering the shore of Prince William Sound and discharges into the upper end of Kenai Lake. Kenai Lake is about 22½ miles long and has an area of 22 square miles. (See Pl. XVIII, *B*.) It seems probable that it was formed by the deposition of gravels in the lower part of the valley by the glacier which formerly occupied it, and possibly the lake was scraped out and deepened by the same agency. Streams entering Kenai Lake are Porcupine, Ptarmigan, Trail, and Quartz creeks. Kenai River commences at the outlet of the lake and in the 16 miles to its entrance into Skilak Lake is joined by Juneau and Cooper creeks and Russian River. Skilak Lake is 18 miles long and has an area of 38 square miles. No important drainage comes into it. Below Skilak Lake Kenai River follows a tortuous course of about 50 miles through the flat, plateau-like country to Cook Inlet. Two large tributaries, Killey and Funny rivers, enter from the south in this section.

The eastern part of the basin is characterized by the rugged mountains and glaciated valleys that have already been noted. The former glaciers have also left their mark in the lakes which are found on several of the tributaries. Both of these features are favorable to the development of water power, since heavy falls are usually concentrated near the point where the hanging valley breaks into the main one, and since also the lakes supply possible sites for storage reservoirs. Comparatively heavy grades are found on all the streams, at least over considerable portions of their courses.

KENAI RIVER BETWEEN KENAI AND SKILAK LAKES.

Kenai and Skilak lakes, or Upper and Lower Kenai lakes as they are locally known, lie 460 and 150 feet, respectively, above sea level. Thus, the fall of the river in the 16 miles between the lakes is approximately 310 feet, and, as determined by aneroid, this fall is distributed akout as follows: 60 feet from the Coopers Landing at the outlet of Kenai Lake to the camp of the Kenai Dredging Co., about 3½ miles; 70 feet from this point to the mouth of Russian River, a distance of 3 miles; and about 180 feet in the remaining 9½ miles. There are no falls on Kenai River and rowboats pass down it safely at ordinary stages, but the grade is concentrated in rapid stretches where the current is so swift as to make the hauling of boats up the river very laborious. For 4 or 5 miles below the mouth of Russian River it winds through a flat gravel valley in channels that are constantly shifting and readjusting themselves. Through the remaining section the stream is confined to one permanent channel.

The natural conditions on this stream suggest that the water power available could probably be developed most comprehensively by

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means of a diversion dam, which would turn the flow of the stream through a canal to some point lower, where a power house could be built and the fall utilized. Although the fall of Kenai River is sufficient to make power development practicable at many points, some of these points are much more favorable than others. Unquestionably power would first be developed in the vicinity of the rapids, which would limit the choice to three sites. There are rapids about one-half mile below Cooper's Landing, which is at the outlet of the lake; a second noticeably heavy grade in the stream is at Schooner Bend, about 5 miles from Coopers Landing, and a third is in the vicinity of the canyon, about 10 or 11 miles below the same point. Below Kenai Lake the river flows for several miles over immense gravel deposits of unknown depth, but at the canyon mentioned above it passes out of this formation and is confined between narrow rock walls for a short distance. A stable dam upon the gravel of the upper valley would undoubtedly require a pile foundation. In the canyon a dam could probably be founded upon bedrock. Timber cribwork filled with rock is thought to be the most economical type of construction for a dam in this locality under present conditions.

The outlet of Kenai Lake is wide and deep and the banks are comparatively low. These conditions do not favor an economical development of storage on the lake. However, these obstacles are not prohibitive to the construction of a dam if the necessary expenditure were warranted.

The minimum discharge of Kenai River from August 18, 1913, to January 31, 1914, is estimated at 504 second-feet; the average flow for the three following months would probably be considerably less. The discharge estimated would develop about 40 horsepower per foot of fall with an efficiency of 70 per cent at the wheel.

KENAI LAKE AT ROOSEVELT.

On August 18, 1913, a gage was installed on Kenai Lake at Roosevelt and was read each day (except three days in October), until November 30. The stage of the lake is reported to have fallen at a uniform rate from this date until December 15, when the final reading was made. The lake froze over on the night of December 15. Kenai Lake is usually frozen over throughout the winter and remains at a very low stage, but occasionally there are exceptions, for in December, 1911, the glacier at the head of Snow River released a tremendous volume of water, which kept the lake at a high stage for a considerable period, and it is reported that during the winter of 1911–12 the lake did not freeze over.

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Daily gage height, in feet, of Kenai Lake at Roosevelt, Alaska, for 1913.

[Area 22 square miles. Fred C. Bunce, observer.]

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	8.67	9.25	7.08	.....	16	.....	6.90	6.98	6.63	.....
2	.....	8.36	9.06	7.42	.....	17	.....	6.82	6.95	6.60	.....
3	.....	8.30	8.96	7.38	.....	18	8.89	6.78	6.95	6.53	.....
4	.....	8.12	8.85	7.33	.....	19	8.81	6.73	6.91	6.48	.....
5	.....	7.90	8.71	7.35	.....	20	8.82	6.69	6.86	6.41	.....
6	.....	7.66	8.58	7.32	.....	21	8.88	6.89	6.83	6.40	.....
7	.....	7.62	8.29	7.26	.....	22	9.02	7.24	6.77	6.32	.....
8	.....	7.53	8.12	7.16	.....	23	9.08	7.40	6.72	6.26	.....
9	.....	7.44	7.98	7.01	.....	24	9.14	7.64	6.60	6.09	.....
10	.....	7.34	7.80	6.82	.....	25	9.14	8.62	6.53	6.00	.....
11	.....	7.24	.....	6.73	.....	26	9.12	9.34	6.49	5.93	.....
12	.....	7.19	.....	6.71	.....	27	9.13	9.90	6.41	5.90	.....
13	.....	7.14	.....	6.68	.....	28	9.15	9.90	6.35	5.79	.....
14	.....	7.04	7.16	6.66	.....	29	9.09	9.88	6.32	5.72	.....
15	.....	6.88	7.09	6.65	5.03	30	8.80	9.63	6.52	5.66	.....
						31	8.72	.....	6.81	.....	.....

KENAI RIVER AT KENAI DREDGING CO.'S CAMP.

On August 19, 1913, a gage was installed on Kenai River at the camp of the Kenai Dredging Co., 3½ miles below Coopers Landing and about 1½ miles below the mouth of Juneau and Cooper creeks. Two discharge measurements were made at this point from a boat. For a considerable part of September and October it was not possible to obtain readings on this gage, and for these periods the daily discharge has been computed from measurements referred to the gage on Kenai Lake at Roosevelt and readings on that gage.

The Roosevelt gage is about 17 miles from the lake outlet at Coopers Landing and would give a fairly satisfactory indication of the discharge from the lake; but strictly it would not show the discharge at the dredging camp, because Juneau and Cooper creeks enter between the two points. However, it seems that the inaccuracy involved in this assumption can not be great, because there appears to be a fairly well defined relation between the readings of the two gages. For determining the discharges the readings on the Roosevelt gage were taken to the nearest tenth.

The discharge measurements are too few for a very accurate determination of the rating curve, especially at the lower stages, but since the results present the best available information on the flow of an important stream they are here published. The probable error of the monthly means should not exceed 15 per cent.

Kenai River falls very low in the winter, as is shown by the record for January, and it is said that it is often possible to wade across it with ordinary rubber boots. The rapids do not usually freeze entirely over.

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Discharge measurements on Kenai River at Kenai Dredging Co.'s camp, 1913.

Date.	Width.	Area of section.	Mean velocity.	Gage height.		Discharge.
				Dredge camp gage.	Roosevelt gage.	
	Feet.	*Sq. feet.*	*Ft. per sec.*	*Feet.*	*Feet.*	*Sec.-ft.*
Aug. 19	202	816	5.53	7.94	8.81	4,510
Oct. 23	189	462	3.85	6.09	6.72	1,780

Daily gage height in feet, and discharge in second-feet, of Kenai River at Kenai Dredging Co.'s camp for 1913–14.

[Chas. G. Hubbard, observer.]

Day.	1913										1914	
	August.		September.		October.		November.		December.		January.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	7.8	4,280	.....	5,040	6.2	1,920	5.40	1,070	5.00	740
2	.....	.....	7.6	3,960	.....	4,900	6.4	2,160	5.40	1,070	5.00	740
3	.....	.....	7.4	3,640	.....	4,760	6.5	2,300	5.45	1,120	5.00	740
4	.....	.....	7.4	3,640	.....	4,480	6.5	2,300	5.50	1,160	5.10	820
5	.....	.....	7.2	3,320	.....	4,340	6.6	2,440	5.50	1,160	5.10	820
6	.....	.....	7.1	3,160	.....	4,200	6.6	2,440	5.50	1,160	5.00	740
7	.....	.....	7.0	3,000	.....	3,780	6.6	2,440	5.50	1,160	4.90	660
8	.....	.....	6.8	2,720	.....	3,500	6.4	2,160	5.50	1,160	4.80	580
9	.....	.....	6.9	2,860	.....	3,360	6.4	2,160	5.45	1,120	4.70	504
10	.....	.....	6.4	2,160	.....	3,090	6.3	2,040	5.40	1,070	4.80	580
11	.....	.....	.....	2,320	.....	2,800	6.2	1,920	5.40	1,070	4.80	580
12	.....	.....	.....	2,320	.....	2,600	6.2	1,920	5.30	980	4.70	504
13	.....	.....	.....	2,200	.....	2,400	6.2	1,920	5.30	980	4.70	504
14	.....	.....	.....	2,080	.....	2,320	6.1	1,800	5.25	940	4.70	504
15	.....	.....	.....	1,960	.....	2,200	6.1	1,800	5.20	900	4.70	504
16	.....	.....	.....	1,960	.....	2,080	6.1	1,800	5.20	900	4.75	542
17	.....	.....	.....	1,850	.....	2,080	6.0	1,680	5.20	900	4.90	660
18	.....	4,620	.....	1,850	.....	2,080	5.90	1,560	5.20	900	4.80	580
19	8.0	4,620	.....	1,740	.....	1,960	5.90	1,560	5.25	940	4.75	542
20	8.0	4,620	.....	1,740	.....	1,960	5.80	1,460	5.35	1,020	4.70	504
21	8.0	4,620	.....	1,960	.....	1,850	5.80	1,460	5.35	1,020	4.70	504
22	8.0	4,620	.....	2,320	.....	1,850	5.75	1,410	5.30	980	4.70	504
23	8.2	4,980	.....	2,570	.....	1,740	5.70	1,360	5.40	1,070	4.70	504
24	8.2	4,980	.....	2,830	6.1	1,800	5.70	1,360	5.40	1,070	4.70	504
25	8.2	4,980	.....	4,200	5.85	1,510	5.70	1,360	5.30	980	4.70	504
26	8.2	4,980	.....	5,180	5.90	1,560	5.60	1,260	5.30	980	4.80	580
27	8.3	5,160	.....	6,070	5.90	1,560	5.50	1,160	5.20	900	4.80	580
28	8.3	5,160	.....	6,070	5.90	1,560	5.50	1,160	5.20	900	4.70	504
29	8.2	4,980	.....	6,070	5.90	1,560	5.50	1,160	5.20	900	4.70	504
30	8.0	4,620	.....	5,620	6.2	1,920	5.40	1,070	5.10	820	4.70	504
31	7.9	4,440	.....	.....	6.2	1,920	.....	.....	5.10	820	4.70	504
Mean		4,810		3,190		2,670		2,050		1,010		582
Run-off in acre-feet		134,000		190,000		164,000		122,000		62,100		35,800
Maximum		4,440		6,070		5,040		2,440		1,160		820
Minimum		5,160		1,740		1,510		1,070		820		504
Accuracy		B.		B.		B.		B.		C.		C.

PTARMIGAN CREEK.

Ptarmigan Creek drains an area east of Kenai Lake and flows westerly, entering the lake near Roosevelt post office about 5 miles below the head. It is about 4 miles from the mouth of the creek to

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its outlet from Ptarmigan Lake. Much of the water is derived from the thawing of the snowbanks and glaciers of the high altitudes, the glacial origin being indicated by the milky color of the water, which is characteristic of many glacial streams. Probably much of the suspended matter in the water settles in Ptarmigan Lake.

Ptarmigan Lake lies at an elevation about 300 feet above Kenai Lake and is approximately 3 miles long and one-third mile wide. Its outlet is through a narrow canyon with almost perpendicular rock walls; its banks on both sides are high. The site is very accessible and remarkably well adapted for a storage reservoir. It is estimated that a dam could be built 50 feet high with widths of 40 feet and 100 feet at the bottom and top, respectively. Although the data are too incomplete for making definite deductions regarding the flow, it seems reasonable to suppose that the reservoir formed by such a dam would store the run-off of the creek for the greater part of a year and would supply an admirable means for the control of stream flow. It is roughly estimated from the following measurements and by comparison with other records that at least 1,000 horsepower could be produced at this site throughout the year. A suggested plan of power development is by a ditch leading from the lake down the right side of the valley. Such a ditch, 3 or 4 miles long, and a terminal pipe line of moderate length, could probably be made to utilize the greater part of the fall down to the level of Kenai Lake. In some sections it might be necessary to use a flume and in others it might be advisable to carry the water through tunnels, but the utilization of the creek presents no problems whose solution would be difficult or would involve heavy expense.

The following discharge measurements were made on Ptarmigan Creek:

Discharge measurements of Ptarmigan Creek in 1913.

Date.	Locality.	Discharge.	Date.	Locality.	Discharge.
		Sec.-ft.			*Sec.-ft.*
Aug. 16	500 feet below lake outlet	156	Oct. 11	Mouth	92
Oct. 10	do	95	Oct. 20	do	71

FALLS CREEK.

Falls Creek drains a part of the high, rugged area east of Kenai Lake and north of the Ptarmigan Creek basin. It rises in a high glacier and descends with a steep gradient for about 8 miles to the place where it joins Trail Creek, 1½ miles from its mouth. There are falls about 1 mile from the mouth, where the most favorable conditions for power development on the stream are to be found, but the grade is sufficiently steep over many sections of its course to meet the requirements.

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The gold quartz mill of Skeen-Lechner mine is on this creek about 4 miles from its mouth. It is operated by water power in the summer and steam power in the winter, using wood for fuel. A Pelton wheel, 6 feet in diameter, rated at 68 horsepower, is used for running the stamps and an 18-inch wheel for the concentrator and lights. The water is diverted through a ditch 1,000 feet long to the plant, where a head of 112 feet is obtained. The following information regarding the operation of the plant was furnished by P. H. Holdsworth on March 17, 1914.

Steam power was used after November 13, 1913. When cold weather came the creek first froze from the bottom up, but later cut a channel next to the gravel and was estimated to have discharged approximately 180 miner's inches (4.5 second-feet) throughout the winter. At the beginning of cold weather considerable trouble was experienced in passing water through the ditch. It was caused largely by trying to keep the ditch free of ice, but as soon as it became frozen over and covered with snow the bottom and the sides below the ice line were thoroughly thawed. All the water that could be diverted (from 2 to 3 second-feet) at the intake was allowed to pass through the ditch during the winter and no anchor or slush ice was formed. If a bedrock dam had been constructed at the intake, so that all the water could have been diverted, the mill could probably have been operated throughout the winter by water power.

The flow of the creek fluctuates rather widely, as is shown by the accompanying short record. This is due partly to the steep slopes of the drainage basin and the lack of natural storage, in consequence of which the rainfall tends to pass quickly down the stream. The basin possesses no sites favorable for the artificial development of storage. Much of the basin lies in a deep valley and on the northern slope, so that, beginning in October, the sun does not strike these areas for several months and the thawing is very slight. Large quantities of anchor and slush ice flow down the stream during the fall.

A gage was established on Falls Creek on August 23, 1913, about one-fourth mile above its junction with Trail Creek. It was fastened to the right abutment of the Alaska Northern Railway bridge. Gage readings were made until November 7, when the creek was reported as freezing up for the winter.

Discharge measurements of Falls Creek in 1913.

Date.	Locality.	Gage height.	Discharge.	Date.	Locality.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Aug. 17	At intake of Skeen-Lechner Ditch.	.....	[a] 35	Aug. 23	Alaska Northern Ry. crossing.	3.38	72
Oct. 10	.....do.....	.....	[a] 14.3	Oct. 9	.....do.....	2.87	24
Aug. 17	Alaska Northern Ry. crossing.	3.20	51	20	.....do.....	3.45	[b] 15.7

[a] Includes flow of ditch. [b] Ice conditions.

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Daily gage height, in feet, and discharge, in second-feet, of Falls Creek at railroad bridge near Roosevelt, Alaska, for 1913.

[Drainage area, 15 square miles. Joe Irvine, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	3.00	34	3.05	38	2.85	23
2	.....	.....	3.00	34	2.80	20	2.70	15
3	.....	.....	2.95	30	3.00	34	2.65	13
4	.....	.....	2.80	20	3.00	34	2.70	15
5	.....	.....	2.80	20	3.10	42	2.68	14
6	.....	.....	2.80	20	3.00	34	2.65	13
7	.....	.....	2.80	20	2.95	30	2.55	10
8	.....	.....	2.75	18	2.90	26	.....	.....
9	.....	.....	2.70	15	2.88	25	.....	.....
10	.....	.....	2.68	14	2.85	23	.....	.....
11	.....	.....	2.65	13	2.90	26	.....	.....
12	.....	.....	2.65	13	2.86	24	.....	.....
13	.....	.....	2.60	11	3.00	22	.....	.....
14	.....	.....	2.60	11	.....	20	.....	.....
15	.....	.....	2.60	11	.....	20	.....	.....
16	.....	.....	2.50	9	.....	18	.....	.....
17	3.20	52	2.70	15	.....	18	.....	.....
18	.....	52	2.65	13	.....	16	.....	.....
19	.....	50	2.68	14	.....	16	.....	.....
20	.....	50	2.70	15	3.45	16	.....	.....
21	.....	60	2.70	15	2.75	18	.....	.....
22	.....	70	2.80	20	2.75	18	.....	.....
23	3.38	72	3.50	86	2.60	11	.....	.....
24	3.36	69	4.05	173	2.60	11	.....	.....
25	3.38	72	4.75	312	2.55	10	.....	.....
26	3.30	62	3.80	130	.....	10	.....	.....
27	3.30	62	3.40	74	.....	10	.....	.....
28	3.20	52	3.25	57	.....	10	.....	.....
29	3.20	52	3.15	47	.....	20	.....	.....
30	3.10	42	3.10	42	3.10	42	.....	.....
31	3.05	38	.....	.....	2.90	26	.....	.....
Mean discharge		57.0		43.5		22.2		14.7
Second-feet per square mile		3.80		2.90		1.48		.980
Run-off (depth in inches on drainage area)		2.12		3.24		1.71		.26
Maximum		72		312		42		23
Minimum		38		9		10		10
Accuracy		B.		C.		C.		B.

NOTE.—Gage heights affected by ice and discharge estimated Oct. 13–20, 26–29.

GRANT CREEK.

Grant Creek, like Ptarmigan and Falls creeks, has its source in the western slope of the Kenai Mountains, northeast of Kenai Lake, and lies approximately parallel to them on the north of Falls Creek. It drains an area larger than either of these creeks and empties into Trail Creek in the rapid between the Upper and Lower Trail lakes. An important feature of the basin is Grant Lake, whose water surface is about 215 feet above Trail Lake. Its outlet is 1½ miles from the mouth of the creek and it occupies a basin between the steep mountain slopes, approximately 5 miles long and one-half mile wide. Within a short distance from the outlet of the lake the creek de-

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scends through a series of rapids and falls into a narrow box canyon, through which it flows the greater part of the way to its junction with Trail Creek.

Its concentrated fall and the availability of the lake as a storage reservoir are factors which make Grant Creek very attractive as a source of water power. It is roughly estimated, from the measurements below and by comparison with records on other streams, that at least 1,500 horsepower could be developed throughout the year at this site by utilizing storage; but without storage the low-water flow might not be sufficient to produce more than three or four hundred horsepower. Of course, on a hasty reconnaissance the feasibility of development can not be definitely determined, but certain schemes of suggested development may be very briefly discussed.

A plant might be built near the outlet of the lake, utilizing only the head furnished by the falls and rapids near this point. The power house would have to be located in a rather inaccessible deep canyon, and this would present some objectionable features.

A conduit diverting from the lake outlet to a point near the mouth of the creek would have to pass for a considerable distance along the almost perpendicular wall of a box canyon.

There are two low passes, one lying on each side of the lake outlet, through which it would be possible to divert water to a power house near the level of Trail Lake. The pass on the right is about 1½ miles above the outlet. At this point it is about 3,500 feet between the lakes, the summit of the dividing ridge being about 40 or 50 feet above Grant Lake and 1,200 feet from it. A swamp 15 feet above the lake extends over half this latter distance. With the water level of the lake raised by a dam, it would be possible, with a combination of ditches, a tunnel, and a pipe line, to conduct the water to a power plant at the edge of Trail Lake at a comparatively low cost. The pass on the left of the outlet was not examined.

At the lake outlet it is estimated that a dam 20 feet high would have a length of 100 feet at the bottom and of 300 feet at the top. A higher dam would require considerable increase in the top length owing to the low slope of the left bank. The foundation would be of rock.

Only two discharge measurements were obtained on Grant Creek, and the results appear below.

Discharge measurements of Grant Creek in 1913.

Date.	Locality.	Discharge.
		Second-feet.
Oct. 9	Mouth	155
Oct. 18	do	84

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TRAIL CREEK.

The rapid between Upper and Lower Trail lakes, into which Grant Creek discharges, is about one-fourth mile long and has a fall of 8 or 10 feet. A dam raising the Upper Lake 10 feet could be built on a very favorable site, and its length would not exceed 150 feet. The water could be easily diverted around the rapids in a canal. Such a reservoir would overflow several miles of the track of the Alaska Northern Railway, and so might not prove feasible.

QUARTZ CREEK.

Quartz Creek drains a compact area of 104 square miles lying north of Kenai Lake. Its main valley extends from the mouth of the creek, which is 4 miles from the outlet of Kenai Lake, in a northeasterly direction to the point at which it merges with that of Canyon Creek, the two valleys constituting a low pass from Kenai Lake to Turnagain Arm. Near this pass Quartz Creek valley makes a sharp turn up into the mountain on the southeast. Although the creek has much grade in this upper portion, the tributary drainage is too small to meet a demand for large power. From the pass to Devil Creek, a distance of 4 miles, the creek falls 500 feet, and from that point to the mouth, a distance of 6 miles, the fall is about 300 feet. In this lower portion the creek meanders through a wide flat valley for much of the way, and power development would be impracticable, but in the upper part the valley is narrow and the stream is confined to one channel. Here the conditions are more favorable. This section of the creek has the disadvantage of having no means of increasing the storage upon it.

The principal tributaries of Quartz Creek are Devil and Lost creeks. The former comes in from the northwest; its grade is steep, but its drainage area is too small to make it a very dependable source of water supply. Lost Creek rises in Lost Lake, which lies north of Kenai Lake and at an elevation about 800 feet above it. From the lake outlet it flows northwest and then swings around to the southwest, to its junction with Quartz Creek, about 2 miles from Kenai Lake. Lost Creek has a heavy grade over nearly its whole length, which is about 6 miles, and 1½ miles from its mouth there are falls. Lost Lake is 7 miles long and one-half mile wide and bends almost into a semicircle, with the convex side to the south. The outlet is wide and the banks are low. On the south it is about 2 miles through a low pass from Lost Lake to Kenai Lake. At its upper end there is a low pass to the head of Carter Creek, a short tributary of Upper Trail Lake from the south. If power development were contemplated from the water of Lost Lake, these passes are worthy of investigation as points of diversion. Short tunnels through the dividing ridges would probably be neces-

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sary for such a project. One discharge measurement was made on Lost Creek. The result appears in the list of miscellaneous discharge measurements on page 128.

A gage was installed on Quartz Creek on August 24, 1913, at the bridge just above Fairman's cabin, about 7 miles from the mouth and 1 mile above Devils Creek. The gage-height record was kept until November 7, when the creek was reported as freezing up. The results are given below.

Discharge measurements of Quartz Creek at Fairman's cabin in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 24	3.43	83.6	Oct. 18	3.09	46.2
Sept. 4	3.19	58.1			

Daily gage height, in feet, and discharge, in second-feet, of Quartz Creek at Fairman's cabin near Roosevelt, Alaska, for 1913.

[Drainage area, 30 square miles. Emmet W. Shields, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			3.30	66	3.35	72	3.30	66
2			3.27	63	3.30	66	3.25	61
3			3.25	61	3.30	66	3.20	56
4			3.20	56	3.40	78	3.20	56
5			3.18	54	3.40	78	3.19	55
6			3.19	55	3.35	72	3.15	52
7			3.18	54	3.30	66	3.15	52
8			3.12	50	3.30	66		
9			3.12	50	3.28	64		
10			3.10	48	3.25	61		
11			3.10	48	3.20	56		
12			3.10	48	3.28	52		
13			3.10	48	3.32	52		
14			3.10	48	3.40	52		
15			3.10	48		52		
16			3.08	46	3.15	52		
17			3.08	46	3.18	54		
18			3.05	44	3.10	48		
19			3.05	44	3.20	56		
20			3.05	44	3.18	54		
21			3.05	44	3.12	50		
22			3.05	44	3.10	48		
23			3.40	78	3.10	48		
24	3.43	82	3.75	135	3.10	48		
25	3.43	82	3.75	135	3.08	46		
26	3.40	78	3.65	117	3.08	46		
27	3.45	85	3.60	108		48		
28	3.50	92	3.50	92	3.10	48		
29	3.45	85	3.45	85	3.05	44		
30	3.43	82	3.40	78	3.30	66		
31	3.30	66			3.35	72		
Mean discharge		81.5		64.6		57.5		56.9
Second-feet per square mile		2.72		2.15		1.92		1.90
Run-off (depth in inches on drainage area)		.81		2.40		2.21		.49
Maximum		92		135		78		66
Minimum		66		44		44		52
Accuracy		B.		B.		B.		B.

NOTE.—Gage heights affected by ice and discharges estimated Oct. 12–15 and 27.

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JUNEAU CREEK.

Juneau Creek flows almost due south from its source to its junction with Kenai River, 2 miles below Coopers Landing. Its basin presents an example of the typical hanging valley of this section. The upper part of its basin is comparatively broad and flat and it is locally called Juneau Flat, but about 2 miles from its mouth the stream plunges in a series of cataracts into a deep canyon, and when it emerges continues with an increased grade to its mouth. In the vicinity of the canyon the stream drops about 175 feet within one-fourth mile.

Juneau Lake is about 5 miles from the mouth. It is a small body of water and offers little opportunity for storage. The right side of the outlet rises abruptly but on the left the bank has a long gradual slope.

From 500 to 1,000 horsepower could probably be developed at the canyon from about the first of May until the last part of October, but the minimum flow in the winter might not be sufficient to produce more than one or two hundred horsepower. A record of two measurements made on Juneau Creek is given in the list of miscellaneous discharge measurements (p. 128).

COOPER CREEK.

Cooper Creek heads against Resurrection River and flows generally in a northwesterly direction to Kenai River, which it joins 2 miles below Coopers Landing. It rises in Cooper Lake about 5 miles from its mouth, and through most of its course it occupies a deep rock canyon cut in a broad glacial valley.

Cooper Lake is 6 miles long and about one-half mile in average width. It lies just over a high ridge from the lower end of Kenai Lake and its elevation is about 650 feet higher. Near the outlet the creek has a series of falls, and it is estimated that in a distance of 2 miles it drops 500 feet. That amount of fall would be sufficient to develop about 40 horsepower per second-foot of discharge, with an efficiency of 70 per cent at the wheel. Discharge measurements of Cooper Creek are shown on page 128. They are insufficient to make an estimate of the power capacity of the stream, but they indicate that probably at least 1,000 horsepower could be developed for 5 or 6 months of the year. In the winter the minimum flow might not be sufficient to produce more than 200 to 300 horsepower unless storage could be obtained. At the outlet of the lake the banks are low, so that a long dam would have to be built in order to raise the level of the lake.

Stetson Creek, the principal tributary, enters Cooper Creek about 3 miles from its mouth. Hydraulic mining was formerly carried on

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extensively in the stream flat near the mouth of Cooper Creek. The water was supplied from Stetson, Wildhorse, and Kickinghorse creeks. A high-line ditch diverts from Stetson Creek and carries along the mountain slope for 4 miles, then dropping to a lower ditch, through which the water flows for 1¾ miles and finally it passes through about 1,300 feet of flume.

RUSSIAN RIVER.

Russian River drains a long, flat glacial valley which, at its head, meets that of the main valley of Resurrection River and forms a low pass between the two drainage basins. Russian River is tributary to Kenai River about 6½ miles below Coopers Landing. There are two lakes in its basin, called, respectively, the Upper and Lower Russian lakes. The Upper Lake is 5 miles long and one-third of a mile wide, and is approximately 600 feet above sea level. Its outlet is said to afford a good site for a storage dam. From the Upper Lake Russian River flows first northwestward and then bends gradually to the north to its entrance into the Lower Lake, a distance of 6 miles. In the upper part of this stretch the stream meanders through low, buttelike hills which occupy the valley bottom, but in the low part the valley is simply a wide, swampy tundra flat. There is but little fall between the lakes.

The Lower Lake is the smaller of the two, being but 2 miles long and little more than one-fourth of a mile wide. Its elevation is estimated at 500 feet above sea-level. The outlet is wide and the banks are comparatively low. From the outlet of this lake the river flows 2 miles to its mouth and drops 170 feet. A large part of this fall is concentrated near the lake outlet.

Power development between the lakes is impracticable, but on the lower river a large part of the fall could undoubtedly be utilized.

Russian River drains an area sufficiently large to yield a very dependable water supply throughout the summer, and if further storage could be developed on the lakes the river would afford an excellent opportunity for power development. The minimum flow during the period covered by the records below was 57 second-feet. Under a head of 170 feet that flow would develop 769 horsepower, with an efficiency of 70 per cent at the wheel. Without storage the winter flow might not be sufficient to produce more than 25 per cent as much.

A gage was installed on Russian River on August 20, 1913, at a point about one-eighth mile above the mouth. The gage readings are somewhat broken. The final reading was made October 31. The discharge at the mouth does not differ very much from that at the outlet of the Lower Lake, for the tributary drainage between the

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two points is small. One discharge measurement was made of Russian River at the Lower Lake outlet and the result appears on page 128.

Discharge measurements of Russian River at the mouth in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 20	3.60	123	Oct. 6	3.92	259
Oct. 3	3.84	231	22	3.52	95.7

Daily gage height, in feet, and discharge, in second-feet, of Russian River at mouth, for 1913.

[Drainage area, 60 square miles. C. I. Olsen, observer.]

Day.	August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1				115	3.91	260
2				110	3.86	235
3			3.55	105	3.84	225
4				95		250
5			3.48	85	3.96	288
6			3.45	78	3.92	266
7			3.45	78	3.87	240
8			3.45	78	3.84	225
9				75		225
10				70		225
11			3.40	65		200
12				62		200
13				60		175
14			3.36	57		175
15			3.36	57		150
16			3.36	57		150
17			3.36	57		125
18			3.36	57		125
19			3.36	57		125
20	3.60	120		57		100
21	3.61	124	3.36	57		100
22	3.64	136	3.36	57	3.52	96
23	3.68	152	3.44	75		94
24	3.66	144	3.68	152		94
25	3.63	132	4.12	384		90
26	3.63	132	4.30	510		90
27	3.63	132	4.27	489		90
28	3.62	128	4.16	412		88
29		124	4.05	340	3.49	88
30	3.60	120	3.95	282	3.75	182
31		115				180
Mean discharge		130		141		166
Second-feet per square mile		2.17		2.35		2.77
Run-off (depth in inches on drainage area)		.97		2.62		3.19
Run-off in acre-feet		3,090		8,390		10,200
Maximum		152		510		288
Minimum		115		57		88
Accuracy		B.		B.		C.

NOTE.—Discharge interpolated for days on which gage heights are missing.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in the basin of Kenai River in 1913 are shown in the table following.

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Miscellaneous discharge measurements in Kenai River drainage basin in 1913.

Date.	Stream and locality.	Discharge.	Drainage area.	Discharge per square mile.
		Sec.-ft.	*Sq. miles.*	*Sec.-ft.*
Oct. 17	Lost Creek 3 miles below lake outlet	61	22	2.79
6	Juneau Creek at mouth	103	63	1.63
24	....do	58	63	.92
Aug. 21	Stetson Creek at mouth	35	8	4.39
21	Cooper Creek above Stetson Creek	137	35	3.91
Oct. 6	Cooper Creek at mouth	210	47	4.47
24	....do	104	47	2.21
Aug. 20	Russian River ¼ mile below Lower Lake outlet	132	55	2.40

SIXMILE CREEK DRAINAGE BASIN.

GENERAL FEATURES.

Sixmile Creek drains an area of 258 square miles and enters Turnagain Arm about 16 miles from its head, at Sunrise. It is formed by the union of two large branches, East Fork and Canyon, about 9 miles from Sunrise. The basin is characterized by rugged mountains, many of which are between 4,000 and 5,000 feet in elevation. Most of the streams flow in narrow, steep valleys. A few small glaciers are found at the higher elevations.

From "the forks" to Sunrise, Sixmile Creek has a fall of about 325 feet. There are several rapids, and good dam sites exist at several places. The East Fork and its tributaries are admirably adapted topographically for power development. They have an abundance of rapids, falls, and dam sites. (See Pl. XV, *A*, p. 100.) The objection to it is the fact that its winter flow would be very small and there are no available reservoir sites of an ample size for increasing it. There is a small lake at the head of Bench Creek in Johnson Pass, but it would require a long dam to increase its storage, and the effect it could have upon the control of the stream would be slight.

Canyon Creek has a drainage area of 100 square miles at its mouth, in contrast to the East Fork, which has 117 square miles. Canyon Creek and its tributaries closely resemble the East Fork in character. About 8 miles from "the forks" Mills Creek, which has been an important placer mining stream in the past, branches off to the east. It has a very steep grade, but there are no storage sites on it. (See Pl. XVIII, *A*, p. 115.) Its summer flow is large, but in the fall the decreasing temperature reduces it to a mere rivulet. Juneau Creek is a tributary of Mills Creek, from which water has been obtained for hydraulic mining. Canyon Creek heads in two small lakes, called Upper and Lower Summit lakes, respectively, the former being the larger. No great storage could be obtained from either of these lakes.

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SIXMILE CREEK AT SUNRISE.

A gage was installed on Sixmile Creek on August 27, 1913, on the left bank about one-half mile above the mouth, and was read twice each day until November 30. On December 2 the stream was reported as having frozen over except in the rapids.

The discharge measurements were made at a section of the stream opposite the Sunrise post office, about three-eighths of a mile below the gage. Very little drainage comes in between the two points.

Discharge measurements on Sixmile Creek at Sunrise in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 27	5.75	[a] 1,600	Sept. 25	6.95	[b] 6,150
Sept. 6	4.86	597	Oct. 15	4.64	503

[a] Boat measurement. [b] Float measurement.

Daily gage height, in feet, and discharge, in second-feet, of Sixmile Creek at Sunrise for 1913.

[Drainage area, 258 square miles. Adolph Lawson, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	5.10	780	5.30	970	5.25	1,020
2	.....	.....	5.00	700	5.30	970	5.10	780
3	.....	.....	4.95	665	5.15	825	5.00	700
4	.....	.....	4.90	630	5.30	970	4.95	665
5	.....	.....	4.85	600	5.25	920	4.85	600
6	.....	.....	4.85	600	5.15	825	4.80	570
7	.....	.....	4.80	570	5.10	780	4.75	545
8	.....	.....	4.80	570	5.05	740	4.65	495
9	.....	.....	4.75	545	4.95	665	4.75	545
10	.....	.....	4.75	545	4.90	630	4.85	600
11	.....	.....	4.70	520	4.80	570	4.80	570
12	.....	.....	4.70	520	4.80	570	4.65	495
13	.....	.....	4.70	520	4.70	520	4.60	470
14	.....	.....	4.70	520	4.65	495	4.60	470
15	.....	.....	4.75	545	4.70	520	4.55	450
16	.....	.....	4.75	545	4.70	520	4.50	430
17	.....	.....	4.75	545	4.70	520	4.70	450
18	.....	.....	4.75	545	4.65	495	4.80	450
19	.....	.....	4.85	600	4.80	570	4.95	450
20	.....	.....	4.90	630	4.70	520	5.25	450
21	.....	.....	4.80	570	4.65	495	5.20	450
22	.....	.....	4.90	630	4.65	495	5.35	430
23	.....	.....	5.15	825	4.65	495	5.55	430
24	.....	.....	5.65	1,420	4.60	470	5.85	430
25	.....	.....	6.75	5,000	4.60	470	5.95	430
26	.....	.....	5.95	2,220	4.50	430	6.15	430
27	5.75	1,590	5.65	1,420	4.75	545	6.40	430
28	5.55	1,270	5.45	1,140	4.75	545	6.90	400
29	5.35	1,020	5.30	970	4.60	470	7.30	400
30	5.25	920	5.35	1,020	5.70	1,500	7.50	400
31	5.20	870	.....	.....	5.30	970	.....	.....
Mean discharge		1,130		897		661		514
Second-feet per square mile		4.38		3.48		2.56		1.99
Run-off, depth in inches		.81		3.88		2.95		2.22
Maximum		1,590		5,000		1,500		1,020
Minimum		870		520		430		400
Accuracy		A.		A.		A.		A.

NOTE.—Gage heights affected by ice and discharges estimated Nov. 17-30.

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MILLS CREEK 2 MILES ABOVE MOUTH.

On August 25, 1913, a gage was installed on Mills Creek, about 2 miles above the mouth, just below the footbridge near Schmesar's cabin. Gage readings were made until November 2, when the creek froze up. Only two discharge measurements were obtained. The error of the mean monthly discharges is probably within 15 per cent.

Discharge measurements on Mills Creek 2 miles above mouth in 1913.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Aug. 25	3.48	140
Sept. 5	3.02	76.7

Daily gage height, in feet, and discharge, in second-feet, of Mills Creek 2 miles above mouth for 1913.

[Drainage area, 25 square miles. Herman Schmesar, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			3.15	94	3.10	87	2.78	51
2			3.10	87	3.10	87	2.70	43
3			3.05	81	3.00	75		
4			3.00	75	3.10	87		
5			3.00	75	3.10	87		
6			2.95	69	3.20	101		
7			2.95	69	2.98	73		
8			2.90	63	2.93	67		
9			2.88	61	2.90	63		
10			2.88	61	2.82	55		
11			2.85	58	2.82	55		
12			2.82	55		55		
13			2.85	58		55		
14			2.80	53		50		
15			2.80	53		50		
16			2.80	53		45		
17			2.80	53		45		
18			2.80	53		45		
19			2.83	56		45		
20			2.80	53		50		
21			2.80	53	2.89	62		
22			2.83	56	2.80	53		
23			3.25	108	2.78	51		
24			3.50	143	2.75	48		
25	3.50	143	3.90	203	2.73	46		
26	3.45	136	3.80	187		45		
27	3.60	157	3.40	129		45		
28	3.45	136	3.20	101		45		
29	3.30	115	3.20	101	2.72	45		
30	3.25	108	3.20	101	3.10	87		
31	3.20	101			2.85	58		
Mean discharge		128		82.1		60.1		
Second-feet per square mile		5.12		3.28		2.40		
Run-off (depth in inches on drainage area)		1.33		3.66		2.77		
Maximum		143		203		101		
Minimum		101		53		45		
Accuracy		C.		C.		C.		

NOTE.—Gage heights and discharges (estimated) affected by ice Oct. 12-20 and 26-28.

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MISCELLANEOUS MEASUREMENTS.

A gage was installed on Canyon Creek just above the mouth of Mills Creek, but efforts to secure readings were not successful. The discharge measurements made at this point appear in the following list.

One measurement was made of Juneau Creek above all ditch diversions.

Miscellaneous discharge measurements in Sixmile Creek valley in 1913.

Date.	Stream and locality.	Discharge.	Drainage area.	Discharge per square mile.
		Sec.-ft.	*Sq. miles.*	*Sec.-ft.*
Aug. 25	Canyon Creek above Mills Creek	[a] 90	28	3.21
Sept. 4	do	[a] 60	28	2.13
Oct. 14	do	44	28	1.56
Aug. 25	Juneau Creek, 500 feet above upper ditch intake	23	4.4	5.23

[a] Includes flow of ditch diverting from Fresno Creek.

RESURRECTION CREEK DRAINAGE BASIN.

The Resurrection Creek drainage basin lies generally parallel to that of Sixmile Creek, and the principal difference in the topography of the two is that the mountains of the former are more smoothly rounded than those of the latter. The area of the drainage basin is 157 square miles.

Resurrection Creek flows northward and empties into Turnagain Arm at Hope, about 8 miles west of Sunrise. About 1 mile from its mouth the creek emerges from its narrow valley into a wide, gravel-floored flat. The valley bottom ascends gradually up to an elevation of 1,600 feet at a point 16 miles from the mouth of the creek. There is a good opportunity for developing power on the stream in the summer. There are no storage reservoir sites or lakes in the basin. Hydraulic mining has been carried on quite extensively on the stream.

The following discharge measurement was made on the stream above Gold Gulch on August 8, 1913: Discharge, 120 second-feet; drainage area, 105 square miles; discharge per square mile, 1.14 second-feet.

POWER PLANT OF THE SEWARD LIGHT & POWER CO.

The Seward Light & Power Co. operates a hydroelectric plant on Lowell Creek and supplies the city of Seward with light and power. The United States Geological Survey is indebted to Mr. S. M. Graff, the president and manager of the company, for the following information concerning this plant and its operation.

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The Seward Light & Power Co. was incorporated in November, 1905, and was first operated December 1, 1905. Except for a stop of four days in December, 1910, caused by frazil, and occasional stops on Sunday afternoons for washing the plant and cleaning machinery, the operation has been practically continuous since the date of starting. Commencing with the short days in the late fall, it has been the policy of the management to run without making any stops. The longest period of incessant operation of the plant is 98 days, a very creditable record.

The equipment consists of an Allis-Chalmers (Bullock) alternating-current generator, of 225-kilowatt capacity, operated by a Pelton wheel under a head of 360 feet. The water is supplied from Lowell Creek by a line of 12-inch pipe 9,000 feet in length.

It was Mr. Graff's opinion that Lowell Creek will supply the needs of a city considerably larger than Seward is at present. When the demand exceeds the possible output of the present plant the head can be increased by moving the intake farther up the creek. At times a dam built impervious down to the bedrock would be of value in increasing the available water supply.

Two serious problems identified with winter operation of water-power plants on the southwestern Alaska coast are introduced by snowslides and frazil. In the coastal regions the heavy snowfall accumulates on the precipitous mountain slopes in such masses that it finally becomes unstable and starts to slide; in sliding the mass gathers up acres more of snow on the mountainside, and when it reaches the bottom of the narrow valley it often fills it scores of feet in depth. Such slides occur several times during a winter on Lowell Creek. At one time in the early history of the plant a slide came down upon a former site of the intake house, destroying it and killing an employee who happened to be there at the time. The intake was then removed to a point where the topography was such as to guard against the recurrence of such a catastrophe.

On a stream like Lowell Creek the effect of a snowslide is to dam up the creek and cut down the water, and when all the available water is required by the plant the result is a more or less serious reduction of the voltage. Experience has shown that this usually lasts from 10 to 45 minutes. A factor which determines to a large extent the seriousness of the effect is the proximity of the slide to the pipe intake, for obviously a temporary damming of the stream near the intake will reduce the flow more than if it is at a distance.

Mr. Graff has had considerable experience with frazil and an account of it will be of interest. The most serious trouble from frazil occurred December 8–17, 1910. The weather was favorable for its formation, and the creek was not frozen over. When the ice began to

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form, the screen at the intake was removed, for otherwise the ice froze to it and shut off the flow. The ice needles which permeated the water entered the pipe and gradually froze in a coat on the interior surface. As this coat became thicker it reduced the cross-section through which water could flow up to the point when the pressure available at the plant was insufficient for running the wheel. The plant was shut down and the water was drained out of the pipe. Finally, when the creek water became warmer, it was admitted again and gradually cut out the ice. The ice was hard and flinty and broke off in pieces too large for passage through the 3-inch nozzle, so that was removed. The ice then came through in large chunks and the shock on the pipe and wheel was tremendous.

To prevent such occurrences the following procedure has been adopted: Temperatures of the water are taken at the plant twice each day—at noon and at midnight. When the temperature is found to be approaching dangerously near 32° F., the intake screen is removed and the frazil is allowed unobstructed admission to the pipe. Usually the formation of the frazil lasts but a short time and the ice does not freeze on the inside of the pipe to a dangerous thickness before the water becomes warmer and thaws it away. However, if conditions do not change and the ice continues to accumulate inside the pipe, when it has reached a thickness estimated at about 2 or 3 inches—since a thickness greater than this would make chunks of ice too large to pass through the nozzle—the water is shut off. It is not permitted to enter again until it becomes warm enough to cut out the ice. Experience has shown that frazil very infrequently forms for more than a few hours, and by taking these precautions shutdowns of the plant because of it are of very short duration and occur much more infrequently.

Water temperatures have been taken at this plant for a number of years, and since such data are scarce, and also because they are of peculiar interest in illustrating one of the problems of Alaskan water-power development, they are here published.

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Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913.

Day.	October.		November.		December.	
	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.
1908.						
1	.....	.....	35	34	36	36
2	.....	.....	34	33	36	36
3	.....	.....	34	34	36	36
4	.....	.....	34	34	.....	36
5	.....	.....	34	34	36	36
6	.....	.....	34	34	.....	36
7	.....	.....	35	35	35	35
8	.....	.....	35	35	.....	35
9	.....	.....	34	36	36	36
10	.....	.....	36	36	36	36
11	.....	.....	36	36	35	35
12	.....	.....	36	36	35	35
13	.....	.....	36	36	34½	35
14	.....	.....	36	36	34	34½
15	.....	.....	36	38	34	34
16	.....	.....	36	37	34	35
17	.....	.....	37	36	36	36
18	.....	.....	35	36	36	36
19	.....	.....	36	36	36	36
20	.....	.....	.....	36	36	35
21	.....	.....	36	36	.....	35
22	.....	.....	.....	36	36	36
23	.....	.....	35	36	.....	36
24	35	36	36	36	.....	34
25	34	34	36	36	.....	36
26	34	35	36	36	36	35
27	35	35	36	36	33	33
28	35	35	36	36	34	34
29	.....	34	36	36	34	35
30	34	35	37	36	36	36
31	34	35	.....	.....	36	36

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Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913—Continued.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.
1909.																								
1	36	35	34	34	34	34	36	35	37	36	38	36	38	37	40	38	39	38	37	35	36	35	32½	33
2	34	35	35	35	34	34	35	35	36	36	38	36	40	37	41	38	39	38	38	36	34	34	33	33½
3	35	35	36	35	34	.....	35	35	37	36	38	36	40	38	40	38	39	38	36	35	34	34	34	34
4	36	35	35	35	34	34	35	35	38	36	38	36	39	37	.....	38	.....	38	37	36	34	35	34	34
5	35	35	34	34	35	35	36	35	37	36	37	37	39	38	39	38	.....	38	.....	35	35	34	33½	33
6	34	35	34	33	36	35	36	35	37	36	37	36	38	38	39	38	39	38	35	34	34	33	33	33
7	35	35	35	35	36	34	36	35	38	37	38	38	38	38	.....	38	.....	38	36	34	33	33	33	33
8	35	35	33	35	35	35	36	35	37	36	37	36	40	38	.....	38	.....	39	35	34	35	36	32½	33
9	34	34	34	34	36	35	36	36	36	36	37	36	40	38	40	38	.....	38	.....	35	35	34	32	32
10	35	34	35	35	35	34	36	36	37	36	38	37	38	38	39	37	39	38	36	36	34	34	33	32½
11	35	35	35	35	35	35	36	36	37	36	38	36	39	38	.....	38	39	38	35	37	36	36	32½	32½
12	35	35	34	35	36	35	36	36	38	36	40	37	39	38	41	38	.....	38	39	36	36	36	34	34
13	34	34	35	35	36	35	36	35	38	36	38	37	39	38	40	38	41	38	41	37	36	36	.....	34
14	34	34	34	35	34	35	36	35	38	36	38	37	40	38	39	38	40	38	38	36	35	34	33	33½
15	33	34	34	35	36	35	36	35	36	37	38	37	41	38	.....	38	40	38	37	36	34	34	34	34
16	34	34	35	35	36	35	36	36	37	36	38	37	42	38	.....	38	.....	37	37	35	34	33	33	33
17	33	34	36	36	36	36	36	36	38	36	38	37	42	38	40	38	.....	38	.....	35	34	34	34	34
18	34	34	36	36	36½	34	36	36	39	36	38	37	38	38	.....	38	40	38	36	35	34	34	34	33
19	34	34	33	33	35	34	36	36	38	36	38	37	41	38	.....	38	40	38	35	35	34	34	34	34
20	34	34	34	34	34	35	36	36	37	36	38	36	41	38	.....	38	40	36	35	35	34	34	34	34
21	34	34	34	34	36	35	36	36	36	36	40	37	40	38	40	38	37	36	35	34	33	33	34	34
22	34	34	34	34	35	35	37	35	37	36	38	37	41	38	.....	38	.....	37	36	36	32	.....	34	36
23	34	34	35	35	34	34	37	35	.....	36	40	37	39	39	40	38	.....	37	37	36	.....	.....	35	36
24	34	35	35	35	35	36	37	35	38	36	38	37	39	38	.....	38	38	37	.....	35	.....	.....	34	34
25	34	34	35	35	36	35	38	36	38	36	40	37	39	39	.....	38	42	36	37	36	.....	.....	34	34
26	34	34	36	35	34	33	37	35	39	37	39	38	39	38	.....	38	36	34	37	35	.....	.....	34	34
27	34	34	35	35	34	35	37	36	39	37	.....	37	42	38	40	38	37	34	36	36	.....	.....	33	34
28	34	34	35	34	.....	36	36	36	.....	37	40	38	40	38	39	38	.....	35	36	35	.....	.....	34	34
29	34	35	.....	.....	36	35	38	36	38	37	39	37	39	38	.....	38	40	36	37	36	.....	32½	34	33
30	34	34	.....	.....	36	35	37	34	.....	36	40	37	40	38	39	38	36	36	37	36	33½	32½	34	33½
31	34	34	.....	.....	36	35	.....	.....	38	36	.....	.....	42	38	39	38	.....	.....	37	36	.....	.....	34	34

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Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913—Continued.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.
1910.																								
1	33	34	34	34	35½	34½	36	37	.....	36	36½	36	38	37	39	38	40	38	39	38	37	36	34	33
2	34	35	34	35	35½	34½	36	36	36	36	36	36	38	37	38	38	40	38	.....	37	38	37	32½	32
3	34½	34	.....	35	35	34	.....	36	36	36	36	36	.....	38	39	38	40	38	38	37	38	35	33	33
4	35	36	34	34	35	34½	36	36	36	36	38	36	38	38	38	38	.....	38	38	37	36	35	34	32
5	36	35	35	35	35	34	37	35½	.....	36	.....	36	38	37	38	38	40	38	37	37	36	36	32½	32
6	36	35	35	35	35	34½	36	36	36	35	37	36	38	37	40	39	40	38	38	37	.....	34	34	33
7	33½	34	35	35	35	35	36	36	37	35½	37	36	39	38	.....	38	40	38	38	37	33	32	33	32
8	33½	33	35	35	35	.....	35	35	.....	36	38	37	38	37	40	38	40	38	37	36	33	33	33	32
9	34	34	35	35	36	35	35	35	36	35½	.....	36	38	37	39	.....	41	39	.....	.....	33	32	32½	32½
10	34	33	35	35	36	35½	.....	35½	37	36	38	37	38	37	41	38	41	39	.....	.....	33	33	32½	.....
11	33	34	35	35	36	36	36	35½	.....	36	38	36	38	37	41	38	.....	39	.....	38	33	33	.....	.....
12	34	34	35	34½	36	35½	36	35	.....	36	.....	38	40	38	41	39	40	39	38	38	34	34	.....	.....
13	34	34	35	34½	36	36	36	35½	37	36	38	37	39	38	42	39	39	39	38	37	.....	34	.....	.....
14	34	35	35	34½	36	36	36	36	36	36	38	37	39	38	.....	39	39	38	38	36	34	34	33	33
15	34	34	35	35	36	36	36	36	36	36	37	36	38	38	41	39	39	39	38	38	35	35	34	33
16	34	34	36	35½	36	36	36	36	37	36	38	36	39	38	39	39	39	38	38	38	36	35	33½	32½
17	34	34	36	35	36	36	36	36	36	36	37	36	.....	38	39	38	39	38	38	38	35	35	33	33
18	34	34	36	35½	36	36	36	36	36	36	38	36	38	37	40	39	39	38	38	38	36	35	34	33
19	33½	34	36	35½	36	36	36	36	36	36	37	36	38	37	41	39	39	38	38	38	36	36	34	33½
20	34	34	36	35½	36	36	36	36	37	36	37	36	38	38	41	39	38	38	38	38	36	36	34	33½
21	34½	35	35	35	36	35½	36	36	36	36	37	36	38	38	41	38	39	38	38	38	37	35	34	34
22	34	34	35½	35	36	35	37	36	36	36	38	36	40	38	40	39	39	38	.....	37	36	34	35	34
23	34	34	35	34½	36	35½	37	36	37	36	38	36	40	38	40	39	39	38	38	36	35	34	34	34
24	34	34	35½	34½	36	36	.....	36	37	36	38	36	.....	38	40	39	40	38	37	35	35	35	35	34
25	35	35	35	35	36	36	36	36	38	36	37	37	40	38	40	39	39	38	35	35	36	34	34	34
26	34	35	35½	35	36	36	37	36	.....	36	.....	36	41	39	42	39	38	38	34	34	34	33	34	33
27	34	35	35	34	36	36	37	36	37	36	38	36	40	35	.....	39	.....	38	35	34	.....	33	33	33
28	34	35	35½	35½	36	36	36	35½	38	36½	38	36	40	38	40	38	39	38	35	35	33	32	34	34
29	35	34	.....	.....	36	36	37	36	38	36	38	37	41	38	40	38	.....	38	36	36	33	32	34	34
30	34	34	.....	.....	36	36	37	36	37½	36	38	37	40	38	.....	39	39	38	.....	37	33	33	34	33
31	34	34	.....	.....	36	36½	.....	.....	37	36	.....	.....	.....	38	40	39	.....	.....	38	37	.....	.....	34	34
1911.																								
1	35	34	34	34	36	35	36	35	36	35	37	35	38	37	40	38	40	38	39	37	39	38	34	34
2	35	35	34	34	35	34	36	36	36	35	37	35	.....	37	41	38	41	38	38	37	38	38	34	35

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3	36	35	34	34	35	34	36	36	36	35	37	35	38	37	41	38	.....	38	38	38	.....	37	34½	34
4	35	35	34	34	35	34	36	36	.....	35	.....	35	38	36	41	38	40	39	39	37	36	35	34½	35
5	35	35	34	34	35	34	35	36	36	35	37	36	38	36	41	38	40	39	37	37	36	35	35	35
6	35	35	34	34	35	34	35	36	36	35	37	36	40	37	41	38	40	38	38	37	35	34	36	35
7	34	34	34	34	35	34	35	34	.....	35	36	36	39	37	42	38	40	38	37	36	34	33	36	35
8	33	34	34	34	35	34	35	34	36	35	36	36	38	37	41	38	39	38	38	37	34	33	36	34
9	34	34	34	35	34	34	34	34	36	35	37	36	.....	36	40	38	39	38	39	38	34	34	35	34
10	34	34	35	35	34	34	35	35	36	35	37	36	38	37	41	38	40	38	40	38	35	35	.....	34
11	34	34	35	34	33	33	36	35	36	35	36	35	37	37	41	38	40	38	38	38	36	35	34	33½
12	33	34	34	34	33	33	36	35	36	35	37	36	39	37	42	38	39	38	39	38	34	34	34	33
13	34	34	34	34	33	34	35	35	36	35	36	36	40	37	42	40	40	38	41	38	36	35	34	34
14	34	33	35	35	34	34	35	34	.....	35	.....	36	37	37	42	39	40	38	39	38	36	35	33½	34
15	34	34	34	34	34	34	35	35	37	35	37	36	39	37	42	38	40	37	.....	38	36	36	34	33½
16	34	34	35	34	35	34	35	35	37	35	38	36	40	37	41	38	39	37	38	37	36	35	33½	33½
17	34	34	35	34	35	35	35	35	36	35	37	35	40	38	41	38	40	38	38	37	36	34	34	33
18	35	34	35	33	35	35	35	35	36	35	.....	35	40	38	41	38	40	38	38	38	38	33	33	33
19	35	34	34	34	34	34	35	35	36	35	37	36	40	38	41	38	40	38	40	39	.....	33	34	35
20	34	34	35	34	35	34	36	36	36	35	37	36	40	38	41	38	39	38	39	38	33	32½	35	35
21	35	34	35	35	35	34	36	35	36	35	37	36	40	38	41	38	38	38	39	37	33	34	34	33
22	34	34	35	34	35	34	36	35	36	35	38	36	40	38	42	38	39	38	.....	37	34	35	34	33
23	34	33	35	34	36	35	36	36	36	35	38	36	.....	38	40	38	40	38	38	37	35	34	33	34
24	33	33	35	34	35	36	36	35	36	35	36	36	39	38	40	40	.....	38	38	37	36	34	33	34
25	34	34	35	34	36	35	36	35	36	35	.....	36	38	37	39	38	39	38	39	38	35	33	34	34
26	34	34	35	34	35	34	36	35	36	35	38	36	39	38	39	38	39	38	39	38	36	35	34	34
27	34	34	35	34	35	35	35	35	36	35	38	36	39	38	41	38	39	37	39	37	34	35	34	35
28	35	34	36	35	36	36	36	35	.....	35	38	36	39	37	41	38	38	37	38	37	36	35	35	35
29	33	35	.....	.....	36	35	35	35	36	35	38	37	38	37	42	38	38	38	37	37	.....	34	35	35½
30	34	34	.....	.....	35	34	35	35	37	35	37	37	38	37	.....	38	38	37	38	38	35	34	35	35
31	34	34	.....	.....	36	34	.....	.....	36	35	.....	.....	39	38	40	38	.....	.....	38	38	.....	.....	36	35
1912.																								
1	34	35	36	35	35	34	38	35	38	36	40	36	38	37	40	38	.....	38	40	38	39	38	36	36
2	35	35	35	36	35	34	37	35	37	36	.....	37	38	37	40	38	.....	38	40	38	39	37	36	35
3	35	34½	35	35	35	34	36	35	38	36	40	37	38	39	39	39	40	38	40	38	38	37	34	34
4	34	34	36	36	34	34	36	35	38	36	38	36	38	38	.....	38	42	39	39	38	38	37	34	34
5	34	34	36	35	35	35	37	35	39	36	40	37	38	37	39	39	.....	38	39	38	38	36	34	35
6	34	34	37	36	34	34	37	35	38	36	39	36	.....	.....	39	38	39	38	39	37	36	36	34	34
7	.....	34	37	36	34	33	36	36	39	36	39	36	38	36	39	38	40	38	39	38	35	35	34	34
8	34	34	37	36	35	34	37	36	38	36	38	36	39	38	.....	.....	.....	38	38	38	36	35	34	34
9	34	34½	36	35	35	35	37	35	37	36	38	37	39	38	.....	.....	40	38	40	38	36	36	35	35
10	35	34	36	36	.....	35	37	35	36	35	38	37	39	37	.....	.....	39	38	38	38	37	35	36	36
11	35	34	37	36	35	34	37	35	36	35	38	37	39	37	.....	38	40	38	39	38	36	36	36	36
12	34	34	37	35	35	34	37	35	36	35	39	36	38	37	40	38	39	41	39	38	36	35	36	36
13	34	35	36	35	35	34	37	36	38	36	38	37	38	37	41	38	.....	.....	39	38	.....	34	36	36
14	35	34	36	35	34	34	36	36	39	36	.....	36	38	38	40	39	.....	.....	39	38	35	35	36	35
15	35	35	35	35	35	34	36	36	40	36	.....	36	38	38	41	39	.....	.....	38	38	36	35	34	36

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Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913—Continued.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.
1912—Contd.																								
16	34	35	36	35	36	34	37	36	39	36	.....	37	38	37	40	39	.....	.....	39	37	35	34	.....	35
17	36	35	36	36	.....	33	38	36	38	36	38	36	39	38	.....	38	.....	.....	.....	36	36	36	35	34
18	36	35	36	35	35	35	38	36	40	37	40	37	39	38	.....	39	.....	.....	.....	37	34	35	34	35
19	36	35	36	34	36	35	37	36	.....	37	40	37	40	38	.....	38	.....	.....	38	36	.....	35	36	35
20	35	35½	35	34	36	35	38	35	.....	36	40	37	42	38	.....	38	.....	.....	36	36	36	36	35	35
21	36	36	35	33	37	35	39	36	.....	37	38	37	42	38	.....	38	.....	39	37	35	35	35	36	35
22	36	35	33	33	36	36	40	36	39	37	38	37	42	38	.....	38	.....	38	34	33	36	35	35	33
23	35	35	.....	35	36	36	40	36	37	36	38	37	42	38	.....	38	.....	38	33	33	34	35	32	33
24	36	36	34	34	37	35	40	36	37	36	38	37	.....	38	.....	38	40	38	34	33	35	35	33	33
25	36	36	35	35	37	35	38	36	37	36	40	37	39	38	.....	38	40	.....	34	33	.....	34	34	34
26	36	36	36	35	37	35	38	36	38	36	40	37	.....	38	.....	38	.....	.....	34	35	36	35	34	35
27	36	36	36	34	37	35	38	36	38	36	40	37	.....	38	.....	38	.....	.....	.....	36	35	34	35	34
28	36	35	36	35	38	35	.....	36	38	36	39	37	.....	38	.....	38	.....	.....	37	37	34	33	35	34
29	36	35	36	35	35	35	38	36	38	37	.....	37	.....	38	.....	39	.....	38	38	37	.....	35	34	33
30	36	35	.....	.....	36	35	40	36	.....	36	.....	37	40	38	.....	39	.....	38	38	37	36	35	33	33
31	36	36	.....	.....	36	35	.....	.....	39	36	.....	.....	42	38	40	38	.....	.....	37	38	.....	.....	34	33
1913.																								
1	34	33	36	34	35	34	36	35	38	35	38	36	40	37	41	38	40	38	40	38	.....	.....	.....	.....
2	34	34	36	34	35	33	36	34	38	35	39	36	41	38	42	38	40	37	38	38	.....	.....	.....	.....
3	35	35	36	34	35	35	35	33	38	36	40	36	40	38	41	38	40	37	39	38	.....	.....	.....	.....
4	35	35	35	33	36	34	34	33	38	36	39	36	40	38	40	39	40	38	39	38	.....	.....	.....	.....
5	35	35	34	33	35	34	35	34	38	36	39	36	41	38	40	38	40	38	39	37	.....	.....	.....	.....
6	33	34	35	33	35	34	36	35	38	36	39	37	40	38	.....	39	40	38	40	38	.....	.....	.....	.....
7	33	34	35	33	36	35	36	35	38	36	40	37	.....	38	41	39	40	38	38	37	.....	.....	.....	.....
8	34	35	35	34	35	35	36	35	39	36	.....	37	40	38	40	38	41	38	38	36	.....	.....	.....	.....
9	34	35	36	34	36	35	37	34	38	36	.....	37	.....	38	42	38	40	38	38	36	.....	.....	.....	.....
10	34	35	36	35	36	34	37	34	39	36	39	37	42	38	42	38	.....	38	36	35	.....	.....	.....	.....
11	35	35	36	34	35	34	37	35	.....	36	39	37	.....	38	42	38	41	38	36	35	.....	.....	.....	.....
12	35	34	36	35	34	34	34	34	39	36	40	37	41	38	40	38	41	38	36	34	.....	.....	.....	.....
13	34	34	36	35	34	35	36	34	38	36	40	37	42	38	.....	38	41	38	36	35	.....	.....	.....	.....
14	34	34	36	35	36	33	36	33	38	36	39	37	41	39	40	38	41	38	35	34	.....	.....	.....	.....
15	34	34	36	35	34	34	36	34	39	36	40	37	41	38	42	38	41	38	35	35	.....	.....	.....	.....
16	34	34	36	34	34	34	36	35	38	36	38	37	40	38	40	39	41	38	36	34	.....	.....	.....	.....
17	34	34	35	35	34	35	37	35	37	36	38	37	40	38	42	39	41	38	.....	35	.....	.....	.....	.....

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18	34	34	35	35	35	34	37	34	.....	36	38	37	40	38	41	39	40	39	.....	37	.....	.....	.....	.....
19	35	34	35	35	36	34	34	33	38	36	40	38	39	38	40	39	40	38	38	37	.....	.....	.....	.....
20	34	34	35	35	35	34	36	35	38	36	38	37	.....	38	40	39	40	38	37	37	.....	.....	.....	.....
21	34	35	35	34	35	34	36	35	.....	37	40	37	.....	38	40	38	40	38	38	38	.....	.....	.....	.....
22	34	34	35	34	34	33	37	35	38	36	.....	.....	39	38	40	38	.....	41	38	37	.....	.....	.....	.....
23	35	35	36	35	35	35	37	35	38	36	38	38	41	38	41	38	40	38	38	36	.....	.....	.....	.....
24	36	35	36	35	36	34	37	35	38	36	39	38	40	38	41	38	41	39	.....	36	.....	.....	.....	.....
25	35	35	35	35	36	35	38	35	.....	36	38	38	39	37	41	39	40	39	36	34	.....	.....	.....	.....
26	36	35	35	35	36	35	38	35	39	36	40	38	40	37	40	39	40	38	35	34	.....	.....	.....	.....
27	36	35	35	35	36	35	.....	35	38	36	39	38	40	39	40	37	40	38	36	36	.....	.....	.....	.....
28	36	35	36	35	36	35	36	35	38	36	38	38	38	38	40	37	40	38	37	37	.....	.....	.....	.....
29	36	36	.....	.....	35	34	36	35	.....	36	.....	38	38	37	41	37	40	39	39	38	.....	.....	.....	.....
30	36	34	.....	.....	35	34	38	35	38	37	40	38	38	38	41	38	40	38	39	37	.....	.....	.....	.....
31	36	.....	.....	.....	36	34	.....	35	39	36	.....	.....	41	38	42	38	.....	.....	.....	.....	.....	.....	.....	.....

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WATER-POWER SITES.

The topography of the mountainous area of Kenai Peninsula, in common with that of most of the Alaskan coast, is favorable for water-power development. The water supply, as determined principally by the climate and the character and distribution of precipitation, is large in summer and fluctuates widely but is much less in winter. Usually the minimum flow of a stream determines the magnitude of the development which should be made upon it, and therefore a stream that has natural storage sites or that affords sites for artificial storage presents advantages not possessed by other streams, for its minimum flow and the possible capacity of the plant can thus be increased. There are many streams whose minimum flow would suffice for plants of 1,000 to 2,000 horsepower for the six-months' period from May 1 to October 31, but there are few if any streams whose flow would be adequate for the development of more than a few hundred horsepower in the other six months without storage. Such data as are available regarding these sites are included in the description of the basins in which they occur. Except in the Kenai Valley the streams of the peninsula afford few artificial storage sites. If winter power were demanded in excess of that which could be obtained from the natural flow of the stream, it would have to be supplied from some other source.

The several lakes of the Kenai Valley have some tendency to regulate the flow of the streams rising in them and furthermore the possibility of developing more storage upon them furnishes a means for increasing this regulatory effect. Dams could be constructed at any of the lake outlets, and at some of them the sites are exceptionally favorable. On Ptarmigan and Grant lakes dams which would hold in a reservoir nearly the entire annual run-off from their tributary drainage areas could probably be constructed at a reasonable expense. Thus the available power of the stream could be used at nearly a constant rate throughout the year, or it could be drawn upon as desired. (See pp. 114–128.) If winter power is desirable and the necessary expense is justified, the advantage of such a water supply over one obtained from the natural flow of a stream is obvious.

The feasibility of connecting the water powers of this valley into a single hydroelectric system could be determined only by extensive surveys and studies of the water supply; the available data are far too inadequate to warrant conclusions. The most important power sites in this valley lie within a radius of 15 miles. If storage was fully developed and power plants installed where practicable, their interconnection by electric transmission lines would furnish means for obtaining the maximum output of power from the available water supply and its most uniform distribution through the year. It

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seems most probable that any market for power which is likely to materialize in this region would demand continuous power. The primary purpose of the reservoirs in this basin would be to replenish the flow and augment the power output from November 1 to April 30. Any excess of water could be utilized to increase the uniformity of the flow, if that were desired. The run-off available at the various plants, the amount of storage, and the potential value of the water stored in the different reservoirs as measured by the head through which it would act, would be the principal factors in determining the method of manipulating the plants or the release of water from the reservoirs. Even with storage reservoirs developed to their utmost capacity it seems probable that the output of power in summer could considerably exceed that of the winter.

The cost of construction, operation, and maintenance of 8 or 10 power plants, such as this project would involve, would probably exclude it from the class of cheap power, and only great industrial growth in this region would warrant such a development. On the other hand, the construction presents no serious difficulties, and the region is easily accessible, so there is no reason to believe the cost would be prohibitive.

WILLOW CREEK DISTRICT.

GENERAL FEATURES.

Willow Creek district is the common designation of the area that includes the gold fields lying about 20 miles northeast of Knik, a settlement on Knik Arm of Cook Inlet. The district comprises about 90 square miles, and includes the divide between Little Susitna River and the South Fork of Willow Creek, a tributary of Susitna River. This divide is the southwestern extension of the Talkeetna Range, and lies approximately in longitude 149° 20′ west and latitude 61° 40′ north. Willow Creek, augmented by Grubstake Gulch and Wet Gulch from the south, and by a fork from the north formed by Peterson and Purches creeks, flows westerly out of the mountains and into the flat valley of Susitna River, which it joins about 35 miles from the mouth. Willow Creek is about 40 miles long from its mouth to its most remote sources. Grubstake Gulch has been a producer of placer gold in the past, but at present active mining operation in the Willow Creek basin is confined to the quartz claims of the Gold Bullion Mining Co.

The topographic features of the district are varied. The northern part is characterized by steep, craggy mountains; the southern part is occupied by the much less rugged ridge, known as Bald Mountain. Several of the peaks exceed 5,000 feet in elevation. The valleys are U-shaped, glacial troughs ranging in elevation from 1,500

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to 3,500 feet. High up in these valleys the slopes are heavily strewn with coarse glacial débris, broken rock, and talus. The large proportion of void spaces in this formation affords an excellent reservoir for the summer water supply. Ice forms in these spaces during the winter, and by gradually thawing away in the summer it is an important factor in the distribution of stream flow at a time when it is of commercial value for the development of water power for the quartz mills. Practically all snow disappears during the summer. Small scattered glaciers lie at the head of Archangel Creek and a larger one at the head of the main branch of Little Susitna River.

A condition of considerable economic significance in the Willow Creek district is the scarcity of timber suitable either for fuel or for building. In the lower parts of the valleys of Willow Creek and Little Susitna River timber is plentiful and good, but on Willow Creek it does not extend above Wet Gulch and on the Little Susitna above a point about 2 miles below the mouth of Fishhook Creek. Alders and willows fringe the mountain sides to a considerably higher elevation, but they disappear some distance below the places at which the quartz mills have been installed. Mining timber and wood for fuel must be hauled 4 to 8 miles and up steep grades, and the cost of this haulage increases the cost of the wood to a degree which almost prohibits its use for fuel.

A hasty reconnaissance of the water supply of the Willow Creek district was made in September, and such data as were collected are here presented.

Four or five small gold lode mines are being worked in this district,[1] and the indications are favorable for further discoveries.

GAGING STATIONS AND MEASURING POINTS.

The points at which gaging stations were maintained or discharge measurements made on streams in the Willow Creek district in 1913 are listed below, with numbers corresponding to those shown on Plate XIX.

1. **Craigie Creek at Gold Bullion mill.**
2. **Little Susitna River at mile 28.**
3. Sidney Creek at lake outlet.
4. **Fishhook Creek at mile 33½.**

NOTE.—Black-faced type indicates that daily estimates of discharge are available.

CRAIGIE CREEK AT GOLD BULLION MILL.

Craigie Creek rises in the heart of the Willow Creek region and flows southwesterly about 7 miles to join Willow Creek near its head.

The mill of the Gold Bullion Mining Co. is on Craigie Creek about 4 miles from its mouth. Water power is utilized for the operation

[1] See Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 592, pp. 245-272, 1914.

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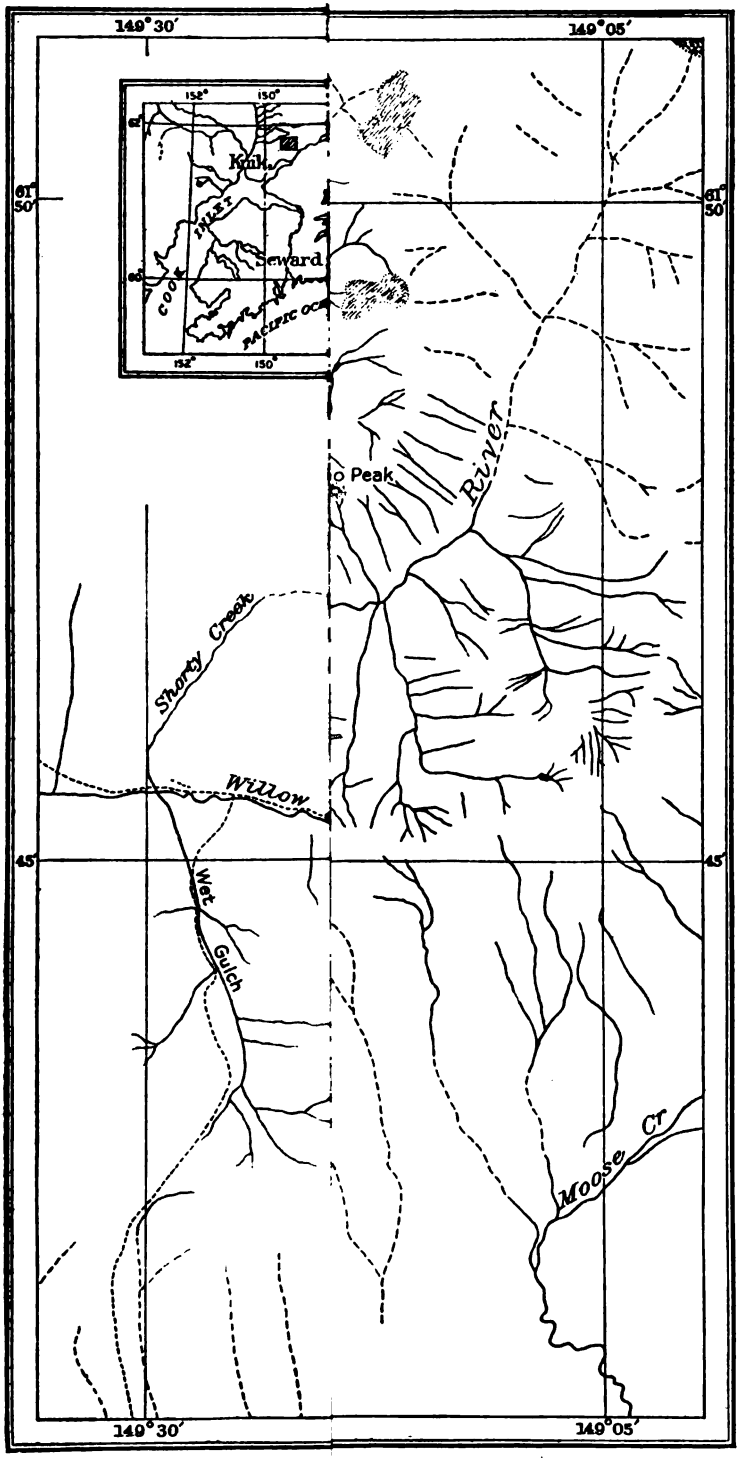

MA POINTS.

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of the plant. A ditch about 1,000 feet long diverts from Craigie Creek to the mill, where it passes through a 12-inch turbine water wheel under a head of about 28 feet. The United States Geological Survey is indebted to the management of the company for a carefully kept weir record on the creek throughout the summer of 1913.

The weir was 10 feet long, sharp crested, of the Cippoletti type, and had end contractions. Readings were generally made three times a day at times closely approximating 7 a. m., 12 m., and 5 p. m. The discharges for each of these readings have been computed and appear with the readings below. During the early part of the season a marked daily fluctuation in the flow is shown, owing to the thawing of the snow and ice in the daytime. It is believed that as a general rule the flow increased up to about 6 p. m. and began to decrease about 7 p. m., reaching the daily minimum the next forenoon. The mean daily discharge shown in the following table was computed from the mean of the discharges at 7 a. m. and 5 p. m., but occasionally the discharge at noon was given some weight in the determination.

The water supply decreased to such an extent the last of August and first of September as to seriously handicap the operation of the mill. During this time it was possible to run but two of the seven stamps.

Height on weir, in inches, and discharge, in second-feet, of Craigie Creek at Gold Bullion mill for 1913.

	7 a. m.		12 m.		5 p. m.		Mean discharge.
	Height.	Discharge.	Height.	Discharge.	Height.	Discharge.	
June.							
1	.....	.....	.....	.....	.....	.....	18
2	7	14	7¼	18	9¼	22	18
3	8⅜	19	8¼	19	11⅛	31	25
4	9¾	24	10	25	13⅜	40	32
5	11¼	30	11¾	32	14¼	44	37
6	11¾	32	12⅜	34	15⅝	48	40
7	12½	35	12½	35	16	50	42
8	12¾	36	16¼	51	17⅜	58	47
9	14½	42	15⅝	48	18¾	64	53
10	15	46	14¼	44	15½	48	47
11	12½	33	12¾	36	13¾	40	36
12	11⅜	30	13¼	38	14⅛	45	38
13	12¼	36	13⅜	40	15½	48	42
14	13¾	40	.....	.....	.....	.....	45
15	13¼	38	16½	53	19⅞	70	54
16	14¾	44	16¾	54	19¼	66	55
17	14½	42	14⅝	44	18¾	64	53
18	13¾	41	14¼	42	18⅛	61	51
19	14⅝	44	14⅛	42	16¾	54	49
20	12¾	36	12	33	15	46	41
21	11¾	30	10⅝	27	13¾	38	34
22	11¾	32	11½	31	15⅛	48	40
23	11¾	32	12	33	15⅜	49	40
24	11⅝	31	11⅝	30	15¼	47	39
25	11⅝	36	11⅞	32	13½	39	34

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Height on weir, in inches, and discharge, in second-feet, of Craigie Creek at Gold Bullion mill for 1913—Continued.

	7 a. m.		12 m.		5 p. m.		Mean discharge.
	Height.	Discharge.	Height.	Discharge.	Height.	Discharge.	
June—Continued.							
26	11½	29	11	29	12½	33	31
27	11	29	11½	29	14½	43	36
28	12½	34	11½	32	12½	33	34
29	10⅝	27	9½	24	9½	23	25
30	7½	17	7½	17	8⅝	19	18
July.							
1	7⅝	17	7⅝	16	9½	24	20
2	8½	19	.....	.....	11½	30	24
3	9½	22	10½	27	11½	31	26
4	10½	28	.....	.....	12½	33	30
5	9½	24	9⅝	24	12½	33	28
6	10½	26	.....	.....	10½	25	26
7	8⅝	20	.....	.....	9½	23	22
8	9½	23	.....	.....	8½	21	22
9	7⅝	17	.....	.....	10½	28	22
10	8½	18	9⅝	23	11½	30	24
11	15	46	.....	.....	12½	33	40
12	9⅝	24	9½	22	9⅝	23	24
13	8½	21	8½	19	12½	36	28
14	9½	22	9⅝	23	9½	23	22
15	8½	20	7½	16	7½	16	18
16	7½	17	7½	16	7½	16	16
17	7	15	.....	.....	7½	16	16
18	6⅝	14	6⅝	13	6½	14	14
19	6½	12	6	12	6½	12	12
20	9½	22	.....	.....	8½	21	22
21	6½	14	6⅝	14	6⅝	13	14
22	7½	16	7⅝	16	7½	16	16
23	7	15	6½	14	6½	14	14
24	6½	13	6	12	6½	14	14
25	7	15	6½	14	6½	14	14
26	7⅝	16	8⅝	20	9⅝	23	20
27	8⅝	19	8	18	7½	17	18
28	7½	15	8½	18	8½	21	18
29	7½	16	6½	13	6⅝	14	15
30	6½	12	6½	12	6	12	12
31	5½	11	6½	12	6½	14	12
August.							
1	5⅝	11	5⅞	11	.....	.....	11
2	5½	10	5⅝	10	5⅝	10	10
3	5⅝	10	5½	9.6	5⅝	10	10
4	5⅝	10	5½	9.2	5⅝	10	10
5	5½	9.2	5	8.9	5⅝	10	9.6
6	7	15	6½	13	6½	12	14
7	6	12	6	12	6	12	12
8	5⅝	11	5⅝	11	6½	12	12
9	5⅝	10	5½	9.2	6	12	11
10	6	12	5⅝	11	5½	10	11
11	5½	10	5½	9.6	5½	10	10
12	5½	9.2	5	8.9	5½	9.2	9.2
13	5½	9.2	5	8.9	5	8.9	9.0
14	4½	8.2	4⅝	7.9	4⅝	7.9	8.0
15	4½	7.6	4⅝	7.3	4⅝	7.3	7.4
16	4½	6.9	4½	7.6	4⅝	7.9	7.4
17	4½	6.6	4	6.3	4½	6.6	6.6
18	4½	7.6	4½	7.6	4⅝	7.9	7.8
19	8½	20	13½	41	12	33	26
20	10⅝	28	9½	24	9½	24	26
21	7½	16	7½	15	7½	15	16
22	6½	13	6½	12	6½	12	12
23	5½	11	5½	11	5⅝	11	11
24	5½	10	5½	10	5½	11	10
25	5⅝	11	5⅝	11	5½	11	11

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Height on weir, in inches, and discharge, in second-feet, of Craigie Creek at Gold Bullion mill for 1913—Continued.

	7 a. m.		12 m.		5 p. m.		Mean discharge.
	Height.	Discharge.	Height.	Discharge.	Height.	Discharge.	
August—Continued.							
26	7⅜	17	9⅝	23	11½	29	23
27	15½	50	16	50	14	41	46
28	10	25	9⅝	24	9⅝	24	24
29	.....	.....	.....	.....	.....	.....	18
30	.....	.....	6¼	12	.....	.....	12
31	6⅞	14	7¼	16	7⅞	16	15
September.							
1	6⅝	13	.....	.....	6¼	12	12
2	5½	11	5⅝	11	.....	.....	11
3	5¼	10	5⅛	10	5¼	9.6	9.8
4	5	8.9	4½	8.5	4¼	8.2	8.6
5	4⅝	7.9	4½	7.6	4½	7.6	7.8
6	4 1/16	7.1	.....	.....	4¼	6.9	7.0
7	4⅛	6.6	4	6.3	4	6.3	6.4
8	3¾	6.0	3⅞	6.0	3 15/16	5.9	6.0
9	3¾	5.7	3¾	5.7	3⅝	5.5	5.6
10	3⅝	5.5	3½	5.2	.....	.....	5.3
11	3 7/16	5.1	3⅜	5.0	.....	.....	5.0
12	3 1/16	4.3	2 15/16	4.1	.....	.....	4.2
13	2⅞	3.9	2 11/16	4.1	2 15/16	4.1	4.0
14	2 15/16	3.6	3 5/16	4.8	3¼	4.7	4.2
15	3 5/16	4.6	3 5/16	4.6	3 5/16	4.6	4.6
16	3¼	4.5	3¼	4.5	3¼	4.5	4.5
17	3⅜	5.0	3¼	4.7	3⅜	5.0	4.9
18	3¼	4.7	3⅛	4.5	3⅛	4.5	4.6
19	3	4.2	3	4.2	2 15/16	4.1	4.2
20	2⅞	3.9	.....	.....	.....	.....	3.9
21	2⅞	3.9	2⅝	3.7	2 11/16	3.6	3.8
22	2¾	3.7	3¾	5.8	.....	.....	10
23	17¼	59	13⅝	40	11	29	44
24	10⅝	26	.....	.....	10⅝	26	26
25	8¼	19	.....	.....	.....	.....	16
26	.....	.....	4 5/16	7.1	4	6.3	7.1
27	3¼	4.7	3	4.2	2¾	3.7	4.2
28	2¾	3.7	.....	.....	.....	.....	3.7
29	.....	.....	.....	.....	.....	.....	3.7
30	4½	7.6	.....	.....	.....	.....	7.6

Monthly discharge of Craigie Creek at Gold Bullion mill for 1913.

Drainage area 2.8 square miles.

Month.	Discharge in second-feet.			Second-feet per square mile.	Run-off (depth in inches).	Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.				
June	55	18	38.4	13.7	15.29	2,280	B.
July	40	12	20.1	7.18	8.28	1,240	B.
August	46	6.6	13.7	4.89	5.64	842	B.
September	44	3.7	8.32	2.97	3.31	495	B.

LITTLE SUSITNA RIVER.

Little Susitna River rises in a glacier a few miles northeast of the Willow Creek region and flows in a general southwesterly direction to the point at which it is joined by Archangel and Fishhook creeks,

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which take the drainage opposite the head of Willow Creek and flow generally to the south and east. About 20 miles from its head the Little Susitna emerges from the hills and bends to the west, following the base of Bald Mountain, from which it receives many small streams. It continues on this course about 30 miles until it is well out into the flat, swampy valley of Susitna River, and then turns more to the south and 20 miles beyond enters Cook Inlet.

Two discharge measurements of the Little Susitna were made about 14 miles from its head and 3 miles below the mouth of Fishhook Creek, at a point just above the highway bridge which crosses it about 28 miles from Knik. Gage heights were obtained for a short period, but the measurements are insufficient for estimates of daily discharge.

Discharge measurements of Little Susitna River at mile 28.

Date.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
	Feet.	*Sec.-feet.*	*Sq. miles.*	*Sec.-feet.*
Sept. 10	3.75	141	61	2.31
Sept. 13	3.70	135	61	2.21

Daily gage height, in feet, of Little Susitna River at mile 28 for 1913.

[Drainage area, 61 square miles. Hule Goodell, observer.]

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1			11	3.70		21	3.70	
2		3.80	12	3.70		22		
3			13	3.69		23		
4			14	3.66		24		
5			15	3.65		25		
6			16	3.64		26		
7			17	3.66		27		
8			18	3.64		28		
9			19	3.60		29		
10	3.76		20	3.60		30		
						31		

ARCHANGEL CREEK.

Archangel Creek rises in the rugged mountains of the northern part of the Willow Creek district and flows in general to the south and east. Like all other streams in the vicinity, it has heavy grades and is well adapted for supplying power to run small mills when the water supply is sufficient. The water power is likely to be utilized, as there are a number of quartz prospects on the creek and its branches.

The following discharge measurement was made on Sidney Creek, a branch draining a southern slope of the basin, at the outlet of a small lake, where it is proposed to divert water for running a mill.

September 12, 1913: Gage height, 3.11 feet; discharge, 1.88 second-feet; drainage area, 1.1 square miles; discharge per square mile, 1.71 second-feet.

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The discharge probably represents about the minimum for the summer. The lake outlet is at the point where a hanging valley breaks into the main valley, and the creek falls more than 200 feet in one-fourth mile. Without doubt the water supply is sufficient for running a small mill the greater part of the summer.

FISHHOOK CREEK.

Fishhook Creek drains the area south of Archangel Creek. The mills of the Gold Quartz and Free Gold Mining companies are near its head, and both have small hydraulic plants. During the last of the summer they were handicapped by shortage of water. The Free Gold Mining Co. was put to considerable expense in building ditches to gather in all the drainage available, but even this was inadequate during the latter part of the summer and it was necessary to use a gasoline engine for auxiliary power.

A few gage heights were obtained and the following discharge measurement was made on Fishhook Creek at a point 1¾ miles below the site of the mill used by the Free Gold Mining Co. in 1913 and above the mouth of the first large tributary on the right, about 2½ miles from the mouth and about 33½ miles from Knik.

September 12, 1913: Gage height, 3.24 feet; discharge, 12.6 second-feet; drainage area, 4.7 square miles; discharge per square mile, 2.68 second-feet.

Daily gage height, in feet, and discharge, in second-feet, of Fishhook Creek at mile 33½ for 1913.

[Drainage area, 4.7 square miles. H. C. Emery, observer.]

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1			11			21	3.30	
2		3.26	12	3.25		22	3.35	
3			13	3.25	3.60	23		
4		3.23	14	3.25	3.60	24	3.40	
5		3.00	15	3.23	3.15	25	3.42	
6		3.00	16	3.25	3.10	26		
7			17	3.23	3.03	27		
8		3.20	18	3.20	3.05	28	3.43	
9			19			29		
10			20			30	3.30	
						31		

NOTE.—Gage heights affected by ice Oct. 5-18.

DEVELOPED WATER POWERS.

Three water-power plants have been installed in the Willow Creek district for the operation of gold quartz mills, as follows: The Alaska Gold Quartz Mining Co. develops 15 to 20 horsepower on Fishhook Creek by Pelton wheel under a head of 120 feet, using the power to operate a 4-stamp mill; the Alaska Free Gold Mining Co. develops about 25 horsepower on Fishhook Creek by a Pelton wheel under a head of 35 feet, using the power to operate a Lane mill; the Gold

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Bullion Mining Co. develops about 25 horsepower on Craigie by a turbine wheel under a 28-foot head and uses the power to operate a 7-stamp mill.

The water supply for these plants is sufficient for their operation only about three or four months during the summer.

WATER-POWER SITES.

Up to the present the only water-power developments which have been justified by the ore prospects of the Willow Creek district have been those directly at the mill sites from the water supply available at those points. These mill sites are so far up the stream that the tributary drainage area is too small to furnish the necessary supply in dry seasons for even the present small plants. Consequently, the plants must be partly or wholly shut down at these times or the water power must be supplemented from other sources. The cost of auxiliary power in these inaccessible regions is so great as to be prohibitive unless the ore is very rich. At one of the mills it was stated that cordwood costs $40 per cord, and that gasoline, which was there used, costs 70 cents per gallon at the mill. Water-power development in winter is impossible on these sites.

The first and easiest method of supplying the deficient power is by increasing the effective head at the plant. This can usually be accomplished easily, for the streams have heavy grades and much head can be obtained in comparatively short distances. In such a plant there would usually be a small flow of water acting under a high head. Wheels for such installations as would sometimes be desired in this region are not carried in the regular stock of water-wheel manufacturers, but it is believed that if the conditions under which they were to operate were known, wheels specially designed could be secured which would give good results.

Another method of solving the power problem is to develop electric power on the lower stretches of the streams where the flow is larger and more dependable and transmit it to the property. A scheme for cooperation in the development of hydroelectric power on the Little Susitna River for the common use of the mining companies of the region has already been proposed. In the vicinity of the mouth of Fishhook Creek the Little Susitna has a fall of about 150 feet to the mile. The valley in this section varies from the U-shaped glacial form to a narrow rock canyon, and it is everywhere filled with heavy granite bowlders. Concentrated fall and the topography make some sites more favorable for power development than others. The most suitable type of development is probably a diversion dam, built only high enough to divert the required amount of water, and a combination of canal and pipe line for carrying the water to the wheel.

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The flow of the Little Susitna for six or seven months of the year under the head that it is possible to utilize would probably be ample for any power requirements that are likely to arise in this district. The discharge on September 13 at mile 28 was 135 second-feet, or 2.21 second-feet per square mile. That flow would develop about 11 horsepower per foot of fall, with an efficiency of 70 per cent at the wheel. With a flow of 0.5 second-foot per square mile about 2.4 horsepower could be produced for every foot fall.

Little is known of the winter flow, but judging from the climatic conditions which prevail in this region it must fall to a very low stage. If winter operation was desirable and the stream flow was not found to be sufficient to provide the power, the closeness of the Matanuska coal fields affords a possible solution of the problem. If these coal fields are developed, it should be possible to furnish fuel for an auxiliary steam plant operating in conjunction with the hydroelectric plant at a comparatively low figure.

Except that the plant would be more remote from the coal fields, hydroelectric power could be generated on the lower part of Willow Creek quite as well as on the Little Susitna, if a central power plant in that vicinity should promise to be more convenient. Such a plant as is suggested would involve considerable expense, but unquestionably would have many offsetting advantages. The feasibility of the project depends on the future promise of the mining industry in the region. If the ore deposits are sufficiently large, the outlay would be justified.

COST OF POWER.

Under ordinary conditions water power is cheaper than steam power. There are, however, so many unfavorable conditions that may have to be overcome in the installation and operation of a water-power plant that its cost, compared with other sources of power, should be carefully considered before definitely deciding in its favor.

Ordinarily, the cost per unit of power developed is much less for a large plant than for a small one. At the present time the industries in the area considered in this report do not require power in large quantities. Aside from railway operation, there are no power requirements aggregating 1,000 horsepower within the province of any one water-power site. Energy is needed principally for the operation of small mines and for lighting. With few exceptions a 200-horsepower plant would be ample. Under such conditions a development may be very expensive, whereas if the same power site was developed to its maximum capacity the energy might be sold at a much lower figure if a market could be obtained for the entire output.

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In order to obtain continuous water power throughout the year it will be necessary on most of the streams to provide storage to assure a sufficient water supply during the winter. Otherwise an auxiliary source of power, such as a steam or gas engine plant, must be provided. In either case the initial expense would generally be considerably greater than it would be if a steam or gas engine plant alone was installed. Most of the mines are small, with a rather uncertain future, for which reason the operators prefer to keep the first cost of their plants as low as possible, even though they must bear a heavier operating expense. When an ore body is worked out the chances are that the power plant that was used in recovering the ore will become practically valueless. It is therefore evident that for a small ore deposit a high rate of depreciation must be charged against the plant.

The cost of installing and operating a water-power system is affected by such an infinite variety of conditions that each development becomes a problem peculiar to itself, and cost data from other installations are of uncertain value. A factor that should tend to produce low installation costs for power development in southern Alaska is the fact that most of the power sites are near tidewater, thus permitting the equipment to be landed near the site at a minimum of cost. Another item of expense that will not usually enter into the cost of development in Alaska to any great extent is the acquisition of rights of way and flowage rights. The streams are, as a rule, more valuable for water power than for other uses, such as domestic supply, irrigation, or navigation, and therefore a conflict of interests will not arise, as so frequently happens in many localities in the States.

The item of expense that tends to increase the cost of construction work in Alaska as much if not more than any other over similar work in more populous countries is that of wages. Wages are high not only because of the high cost of living but also because of the isolated position of the country with respect to labor markets. An increase in wages is also warranted by the rather unfavorable conditions under which men are frequently required to live.

Several small hydroelectric plants ranging from 100 to 350 horsepower have been installed along the coast between Cordova and Seward, and from indefinite cost data that are available regarding three of them the average cost of installation appears to have been about $150 per horsepower. So far as can be learned the plants were constructed under rather unfavorable conditions (one plant was constructed during the spring when there was from 5 to 15 feet of snow at the site), and undoubtedly represent a somewhat higher initial cost than would ordinarily be necessary. The water supply, however, is not sufficient to develop the rated capacity of the generating

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equipment during low-water period. Therefore, if dams were constructed that would create adequate reservoir capacity to assure enough water during the winter the cost of the above installations would probably approach $150 per horsepower, even though the plant were installed under the most favorable conditions.

The following description and estimated cost of installation and operation of a hydroelectric plant in southeastern Alaska is taken from Western Engineering, January, 1914. It is reported that the scheme of development described in the article has since been modified.

LONG LAKE POWER DEVELOPMENT.

By E. P. Kennedy.[1]

Long Lake, which lies about 2 miles from the beach at an elevation of 727 feet, has an area of 3.1 square miles. It is situated near Speel River, between Ketchikan and Skagway, 35 miles southeast of Juneau, Alaska. Water measurements for eight months and an estimate for the remaining four give a yearly run-off of 21,757 million cubic feet, and as the drainage area is taken at 32.4 square miles the above run-off amounts to 24 feet, or an equalized yearly flow of 689 cubic feet per second. The initial plant will use 300 second-feet, which is equivalent to a run-off of 10.4 feet over an area of 32.4 square miles.

The power plant is to be situated near Second Lake, 2,000 feet from and 535 feet below Long Lake and about 1½ miles from the beach. This plant will consist of two units, each 5,000-kilowatt capacity and each to be direct connected to a water turbine utilizing 300 second-feet.

To be assured of a continuous flow of 300 second-feet the lake will be drawn on by tapping with a tunnel or by a siphon to a depth of 12 feet and the two spillways from the lake closed, thus raising the lake level 25 feet, giving an available storage of 37 feet.

The cost of this power installation would be:

Power house with two 5,000-kilowatt units, complete	$250,000
Pipe lines, two 60-inch, with head gates	93,594
Closing spillways from lake	10,000
Tapping lake	5,000
Contingencies and incidentals	3,000
Plant for construction	[2]13,882
Total	375,476

Or a capital cost of $37.54 per kilowatt or $27.95 per horsepower.

The cost of operating the above plant would be per year:

General expenses	$6,000
Operating labor	6,000
Supplies, etc	4,000
Total	16,000
Operating cost per year per kilowatt	1.60
Interest and depreciation, 8 per cent on capital cost	3.00
Cost of kilowatt year	4.60
Cost of horsepower year	3.43

[1] Asst. Supt. Alaska Treadwell Gold Mining Co., Treadwell, Alaska.

[2] Original cost of plant $25,882. Value of plant after construction period estimated $12,000, thus leaving $13,882 to be charged to water power system.

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To be assured of a yearly average of 10,000 kilowatts the generators should be run at 25 per cent above normal capacity for 6 months of the year while there is a large excess of water, and thus provide for unforeseen shutdowns.

Surveyed lake area is 3.1 square miles, or 86,423,040 square feet, requiring 20 feet in depth at this area to provide for the required storage.

This storage is obtained by raising the lake level 25 feet and drawing on the lake 12 feet. The increased area obtained by raising the lake will make up for the decreased area by drawing the lake and also provide sufficient storage below the 2 feet of ice.

Power estimate is based on a pipe-line loss of 1 per cent, water-wheel efficiency of 82 per cent, generator efficiency of 93 per cent; total efficiency of 75 per cent from the water. Three hundred second-feet under 542-foot head at 75 per cent will generate 10,320 kilowatts.

From flow measurements the following figures are obtained:

	Measured flow (cubic feet).	Mean discharge in second-feet.[a]	Required flow for 300 second-feet.	From storage (cubic feet).
January	324,187,200	121	803,520,000	479,332,800
February	283,046,400	117	725,760,000	442,713,600
March	374,976,000	140	803,520,000	428,544,000
April	352,512,000	136	777,600,000	425,088,000
May	1,154,390,400	431	803,520,000	.....
June	2,947,104,000	1,137	777,600,000	.....
July	5,340,729,600	1,994	803,520,000	.....
August	4,860,492,480	1,815	803,520,000	.....
September	4,473,792,000	1,726	777,600,000	.....
October	803,520,000	300	803,520,000	.....
November	518,400,000	200	777,600,000	259,200,000
December	324,187,200	121	803,520,000	479,331,800
	21,757,337,280	689	9,460,800,000	2,510,210,200

[a] Inserted by C. E. E.

The foregoing estimates are exceedingly low, and if after construction and operation of the plant they are found to be correct it is believed that the project will be one of the cheapest that has ever been installed.

The cost of $3.43 per horsepower per year, which includes all operating expenses besides interest and depreciation on the capital cost, could be increased several fold and still be much cheaper than steam power with coal selling at cost.

It should be noted that the estimate does not include the construction of a dam, which is often necessary and frequently makes up a large percentage of the total cost.

A point in connection with the above project that is worthy of note—though not pertinent to the cost—is the high rate of run-off on which the capacity of the plant is based. The average yearly flow is estimated to be 689 second-feet or more than 21 second-feet per square mile.

The cost of developing the Silver Lake power site in the Prince William Sound region has been estimated with considerable care by interested parties. Their estimates contemplated a plant of 750 horsepower capacity, a 10-foot dam at the outlet of the lake, and 8 or 10 miles of transmission line at a total cost of about $55,000 or

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a little over $73 per horsepower. This site could no doubt be developed to a capacity of several thousand horsepower without increasing the cost in anywhere near the same ratio.

Estimated cost of operating a 300-horsepower steam plant per year (365 days, 24 hours per day), assuming capital cost of $100 per horsepower, or total cost of $30,000.

Price of coal per long ton	$9	$6	$4	$3
Interest and depreciation, at 10 per cent	$3,000	$3,000	$3,000	$3,000
4 pounds coal per horsepower-hour	42,228	28,152	18,768	14,076
3 engineers, 8-hour shifts, at $5 per day	5,475	5,475	5,475	5,475
3 firemen, 8-hour shifts, at $4 per day	4,380	4,380	4,380	4,380
Oil, waste, and supplies	1,200	1,200	1,200	1,200
Total for plant	56,283	42,207	32,923	28,131
Total per horsepower per year	187.61	140.69	109.41	93.77

Estimated cost of operating steam plant 6 months.

Price of coal per long ton	$9	$6	$4	$3
Interest and depreciation, at 10 per cent	$3,000	$3,000	$3,000	$3,000
4 pounds coal per horsepower hour	21,114	14,076	9,384	7,038
3 engineers, 8-hour shifts, at $5 per day	2,738	2,738	2,738	2,738
3 firemen, 8-hour shifts, at $4 per day	2,190	2,190	2,190	2,190
Oil, waste, and supplies	600	600	600	600
Total for plant	29,642	22,604	17,912	15,566
Total per horsepower for 6 months	98.81	75.35	59.71	51.89

Estimated cost of operating a 300-horsepower hydroelectric plant per year (365 days, 24 hours per day), assuming capital cost of $150 per horsepower and 5 miles of transmission line at $2,000; total cost of system, $55,000.

Interest and depreciation, at 10 per cent	$5,500
4 operators, at $6 per day—2 shifts, with 1 operator at generating and 1 at distributing end	8,760
1 lineman, at $4 per day	1,460
Oil, waste, and supplies	1,000
Total for plant	16,720
Total per horsepower per year	55.73

Estimated cost of operating hydroelectric plant 6 months.

Interest and depreciation, at 10 per cent	$5,500
4 operators, at $6 per day	4,380
1 lineman, at $4 per day	730
Oil, waste, and supplies	500
Total for plant	11,110
Total per horsepower for 6 months	37.03

The purposes of the above tables is not so much to show the actual cost of producing power as it is to give some idea of comparative cost of steam and water power. Although the above figures may be considerably in error, it is believed the assumptions regarding the steam plant are in its favor as opposed to the hydroelectric system, thus

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giving added weight to the final conclusion that the water power is much the cheaper. For example, it is arbitrary what interest and depreciation charges should be made, but it is generally conceded that they should be greater for a steam plant than for a hydroelectric plant, though in this estimate the same charge (10 per cent) is assumed.

The consumption of coal per horsepower-hour is known to vary widely among different plants, but for one of 300 horsepower it is seldom less than 4 pounds and more often 50 to 100 per cent greater. The estimated cost of labor may be questioned, but it should be noted that the total is assumed to be slightly greater for the hydroelectric plant than for the steam, which is far from probable.

The capital cost of steam plants varies between wide limits, due to different types used and the variety of conditions under which they are installed. Average costs for different sizes and types of plants have been determined from a large number of installations in the United States and Canada. For plants with simple noncondensing engines with capacities from 10 to 100 horsepower the unit cost of installation has been found to vary from a maximum of $225 to a minimum of about $75. Larger plants of 100 to 2,000 horsepower with compound condensing engines are somewhat cheaper per unit of capacity, the average cost varying from a minimum of about $50 for the largest to a maximum of about $170 for the smallest. The assumed cost of $100 per horsepower for the plant under discussion is believed to be more likely less than greater than what it would actually cost.

In estimating the cost of steam power it is considered that the energy is to be used near the point where it is generated, but if the market is not near tidewater or a line of railroad it would probably be cheaper to install electric generators and transmit the energy by wire than to transport the fuel, in which case the capital cost of the plant would be considerably greater than that assumed.

Comparative cost of different systems, summarized from previous tables.

Price of coal per ton	$9.	$6.	$4.	$3.
Steam alone per horsepower year	$187.61	$140.69	$109.41	$93.77
Steam plant 6 months + hydroelectric plant 6 months, per horsepower year	135.84	112.38	96.74	88.92
Hydroelectric plant alone per horsepower year	55.73			

In the table above are summarized from previous tables the estimated unit costs of one horsepower per year, from a steam plant alone, from a hydroelectric plant alone, and from a plant using steam and hydroelectric power each for six months. The figures show that

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the cost of water power at $55.73 per horsepower year is only about one-third that for steam with coal at $9 per ton, which is about the minimum price that coal sold for in 1913 at tidewater in south-central Alaska. With coal at $3 per ton, which is probably less than it can be sold for when the Matanuska and Bering River fields are commercially available, the cost of water power is still about 40 per cent less than that for steam. The combined steam and hydroelectric plant is also shown to be more economical than steam alone, even with coal at the minimum figure.

California crude oil is now being used to a considerable extent in place of coal in Alaska, and so long as coal must be shipped from British Columbia or points on the Pacific coast of the United States, the advantage of oil will probably continue, but when local coal becomes available it is doubtful if that condition will persist. Compared with coal, oil weighs about 35 per cent less for equal heat values and occupies about 50 per cent less space. An average ratio in heat values that is frequently used is 3.5 barrels of oil to one ton of coal. The selling price in 1913 at Cordova was $2 per barrel.

Wood is used but little for the development of power. It can not compete with other fuels even under the prevailing high price, except where the timber is locally available and the other fuels must be transported for a considerable distance. About two cords of wood are generally considered the equivalent of one ton of coal.

Gasoline is used to some extent by small power consumers in isolated localities where wood is not available and where lack of transportation facilities demands economy in weight of both equipment and fuel. About one pint of gasoline or denatured alcohol is required per horsepower-hour when the engine is being run under favorable conditions, such as most efficient load, proper compression and time of ignition and most suitable explosive mixture. As ordinarily operated gasoline engines may require several times the above quantity of fuel per unit of power developed. In quantities of 50 to 100 gallons gasoline sold for $0.40 per gallon at points on the coast near Prince William Sound in 1913.

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A WATER-POWER RECONNAISSANCE IN SOUTHEASTERN ALASKA.[1]

By JOHN C. HOYT.

INTRODUCTION.

The territory covered by this report (see fig. 5) includes that portion of southeastern Alaska extending southward from White Pass for a distance of about 350 miles. Detailed investigations of water-power resources were made in three districts of this area—Ketchikan, Juneau, and Skagway. Data were also obtained at Sitka and other points and from conversation with persons familiar with the country.

From Ketchikan the plants of the local power company, the New England Fish Co., and the Metlakatla Fish Co., at Beaver Falls and Sulzer, were visited. The undeveloped possibilities at Hadley, Kasaan Bay, Cholmondley Sound, Georges Arm, Carroll Inlet, Unuk River, and about Sulzer were investigated also.

From Juneau the developments of the Treadwell Co., on Douglas Island, of the Perseverance and other companies, in Silverbow Basin, and of the Amalga Co., at Eagle River, were visited. The conditions in Taku Inlet, including Turner Lake, were investigated and information was obtained in regard to Endicott River and the streams between Juneau and Eagle River.

At Skagway the local power plant and the plant of the Chilkat Fish Co. were visited, and a trip was made over White Pass and another to Haines, from which the Porcupine Creek district was visited.

At Sitka data were obtained in regard to Chichagof Island in Klag Bay.

GENERAL TOPOGRAPHIC FEATURES.

Southeastern Alaska comprises a narrow strip of mainland and a series of islands separated from one another by a network of channels and straits. Both the mainland and the islands are indented with many bays, fiords, and inlets, which, with the other natural conditions, practically cut off all travel except by boat. (See Pl. XX, *A*.)

[1] This report is a reprint with slight changes of article in U. S. Geol. Survey Bull. 442, pp. 147-157, 1909.

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With the exception of small areas of flat lands along the larger rivers and at places along the coast, the entire area is mountainous. The mountains rise abruptly from the shore line and reach a maximum elevation varying from 4,000 feet in the southern part of the area to 7,000 feet in the northern part. Owing to this topography,

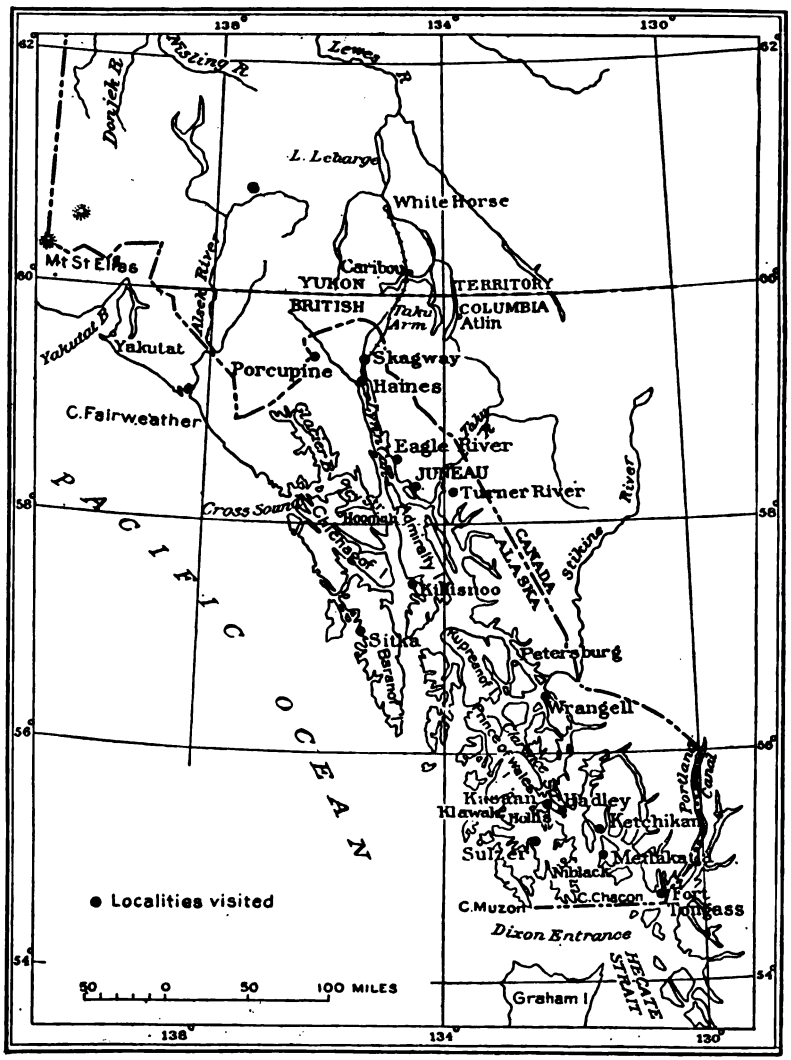

FIGURE 5.—Map of southeastern Alaska.

the streams, with the exception of a few of the larger rivers which come through the mountains from the interior, have small and precipitous drainage areas. Their courses are short and they have a large fall; in fact, many of the streams are made of a series of cataracts. (See Pl. XXI, *A*.)

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A. TYPICAL COAST SCENE.

B. TYPICAL FOREST VIEW.

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A. TYPICAL DRAINAGE AREA AND STREAM.

B. HANGING BASIN SHOWING OUTLET WITH FALLS AT SHORE LINE.

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In the northern part of the area most of the streams head in the glaciers which cover a large portion of the country. In the lower southern part of the area many of the streams head in small lakes which occur a short distance back from the shore line in the hanging valleys that are characteristic of this area. Most of the streams flowing from these lakes are precipitous, and many of them empty into the ocean with a cataract at the shore line. (See Pl. XXI, *B*.) These lakes afford excellent opportunities for storage, as the topography near them is such that a dam can usually be constructed for raising their water level. The most successful powers already developed depend on such storage during a large part of the year, and further development in this region will depend on the availability of such lakes.

GEOLOGY.

In general, there is over the underlying rock of the country but a small depth of soil; hence the facilities for ground-water storage are exceedingly scanty. The underlying rock of the islands and of the mainland up to the foothills is limestone, slate, and schist; in the remainder of the area it is granite.

At the mouths of some of the larger rivers there are alluvial flats and glacial deposits, but the coast is, except in a few places, rocky and steep.

CLIMATE.[1]

As shown in the following tables, the climate is similar to that of the extreme northwestern part of the United States. The last frosts occur not much later than the 1st of May and the first frosts do not come until early in September. The number of growing days, therefore, averages about 180.

The winter temperature ranges from 10° below to nearly 60° above zero; the summer temperature ranges from 35° to 80°, with occasional extremes between 85° and 90°.

Precipitation varies considerably in different portions of the area. Along the west coast and in the area along Dixon Entrance, which is exposed to the direct winds from the Pacific, it is rather high, ranging from 130 inches a year at Fort Tongass to 88 inches at Juneau. In passing inland it decreases and at Skagway is only 21 inches.

A disagreeable feature of the country is the large number of rainy days, which averages about 200, except in the vicinity of Skagway, where it is less than 100. The rains are usually not heavy. Notwithstanding the great precipitation, it dries off quickly after showers, a fact which indicates that the humidity is low.

[1] For more complete records and discussions of climate see pp. 15–34 of this volume.

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Temperature and precipitation in southeastern Alaska.[a]

Month.	Fort Tongass (1 year,[b] 16 months—June, 1868, to September, 1870).				Fort Wrangell (2 years, 40 months—May, 1868, to August, 1882).			
	Temperature (°F.).		Precipitation.		Temperature (°F.).		Precipitation.	
	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.
January	47	6	12.92	18.5	47	− 4	6.07	17.6
February	45	23	10.79	21.5	58	2	8.11	20.0
March	59	− 2	8.21	17.5	54	−10	2.89	12.6
April	60	33	9.57	19.0	64	24	4.11	16.6
May	70	38	7.70	15.5	78	35	3.71	18.6
June	75	43	6.66	10.3	86	38	3.56	13.7
July	91	52	10.58	16.6	82	44	3.69	15.8
August	81	47	6.71	9.6	84	43	3.07	14.3
September	67	38	17.66	19.3	73	38	6.63	17.2
October	58	37	14.11	20.0	67	31	7.36	13.2
November	51	32	15.46	27.0	53	4	11.27	17.8
December	47	24	13.33	19.0	52	− 3	10.41	22.5
Year	.....	.....	133.10	213.8	.....	.....	70.88	199.9

Month.	Killisnoo (16 years, 43 months—May, 1881, to December, 1902).				Juneau (2 years, 30 months—June, 1881, to February, 1897).			
	Temperature (°F.).		Precipitation.		Temperature (°F.).		Precipitation.	
	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.
January	52	− 2	5.98	18.0	50	− 4	10.61	18.1
February	50	−10	4.96	14.9	50	− 4	4.85	11.2
March	52	− 2	4.04	15.0	50	10	6.62	18.7
April	63	15	3.50	11.0	63	13	5.25	15.0
May	76	24	3.38	12.3	71	26	7.36	16.7
June	76	33	2.36	9.9	82	38?	4.99	14.6
July	84	38	4.19	11.7	88	38	5.59	15.5
August	81	36	4.90	16.5	82	38	7.53	15.6
September	69	27	7.79	19.3	85	31	12.19	18.4
October	60	25	7.92	22.3	66	20	10.05	19.8
November	53	1	5.16	16.9	60	− 1	10.47	18.4
December	54	1	4.81	17.6	45	1	8.16	19.8
Year	.....	.....	58.97	185.4	.....	.....	93.06	201.8

[a] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 158–170, 1906.
[b] The records were not continuous, and the number of years given indicates simply the number of continuous twelvemonth periods covered.

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Temperature and precipitation in southeastern Alaska—Continued.

Month.	Skagway (31 months—November, 1898, to December, 1902).				Sitka (17 years, 44 months—November, 1867, to December, 1902).			
	Temperature (°F.).		Precipitation.		Temperature (°F.).		Precipitation.	
	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.
January	42	− 4	0.90	7.5	51	− 2	12.17	16.8
February	44	− 9	.57	2.5	54	− 3	7.47	15.9
March	63	−10	.64	3.0	65	− 1	6.70	18.0
April	61	16	2.39	10.5	70	19	5.61	16.2
May	79	25	.77	4.7	80	28	4.11	16.1
June	90	34	.60	5.0	80	33	3.31	13.6
July	92	39	1.73	5.7	87	35	3.55	14.9
August	80	32	1.51	8.5	82	39	5.84	16.8
September	76	30	3.47	13.5	74	32	9.67	19.5
October	60	16	3.22	12.0	67	25	11.96	21.7
November	51	7	2.17	8.0	59	5	9.80	19.5
December	57	− 4	3.78	11.7	59	7	7.88	18.9
Year			21.75	92.6			88.10	207.9

Dates of freezing in southeastern Alaska.[a]

Station and year.	Last killing frost.	Last frost.	First frost.	First killing frost.	Growing days.
Fort Tongass:					
1868			Nov. 6	Dec. 19	
1869		Mar. 19	Sept. 29	Dec. 17	210
1870		Mar. 14			
Fort Wrangell:					
1869			Sept. 20	Oct. 15	
1875	Mar. 14	Apr. 20	Oct. 5	Oct. 29	229
1876	Apr. 30	June 5	Sept. 14	Oct. 29	182
1882			Oct. 2	Oct. 8	
Juneau:					
1889			Nov. 18		
1890		Mar. 29	Oct. 6		191?
1891		May 2	Sept. 20		141?
1896			Sept. 10	Sept. 19	
1899			Sept. 4		
1900				Sept. 29	
Skagway:					
1899		May 9		Sept. 4	117?
1900	Apr. 9				
1902		July 7	Aug. 27		50?
Killisnoo:					
1884			Sept. 13		
1885			Sept. 28	Oct. 12?	
1888			Oct. 15		
1891		May 6	Sept. 27		143
1892		Mar. 31	Oct. 14		197
1893		May 2	Oct. 18		169
1895			Sept. 3	Sept. 12	
1897			Sept. 27		
Sitka:					
1868		Apr. 21			
1869			Sept. 19		
1870			Oct. 19		
1871				Oct. 31	
1872				Oct. 7	
1873	May 27		Nov. 5		162
1881		May 8			
1900	June 1		Aug. 25	Oct. 1	122
1901				Nov. 1	

[a] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 171-172, 1906.

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VEGETATION.

Owing to the mild temperature, the long days in summer, and the heavy precipitation, the vegetation in southeastern Alaska is very luxuriant. Except where the soil is too shallow or the slopes too rocky, the whole area is covered with dense forests of spruce, cedar, and hemlock and is in the national forests. (See Pl. XX, *B*, p. 158.) Among this timber there is a heavy undergrowth of devil's-club, berries, and other small plants. In the southern part of the area trees vary in diameter up to 6 feet and grow up the slopes to the mountain tops. Toward the north the size of the trees diminishes, the undergrowth is not so heavy, and the timber does not extend to the top of the mountains, which are either small or glacier covered.

Much of the forest is overmature and defective timber is common, but in coves and gullies for several miles back from the coast there are many fine stands of spruce and cedar which have never been injured by fire or cutting.

The logging practice now in vogue takes only the best spruce trees which can be felled into the water or on slopes where they can be skidded in by hand. Of course it is difficult to log in a mountainous country, but much timber can be logged in southeastern Alaska with no more difficulty than attends many operations in the Pacific Coast States, if modern methods are introduced.

So far only the spruce has been used for saw timber, but both spruce and hemlock are undoubtedly good pulp woods. The few sawmills now operating in southeastern Alaska obtain their timber from the national forests, but the supply of timber is much greater than is required by local needs. The Forest Service is desirous of increasing the timber sales, and the present price of stumpage is low—only $1 a thousand board feet. Full information on this subject can be obtained from the forest supervisor at Ketchikan.

Aside from the native growth, garden truck, berries, and the hardy grains and grasses can be raised in all parts of this area. Strawberries, raspberries, and huckleberries grow both wild and cultivated and are of most excellent quality. Grasses and grains are difficult to harvest and cure owing to the large amount of rain.

The areas suitable for agriculture are small and are expensive to bring under cultivation. Agriculture is carried on with difficulty on account of the swampy condition of the ground, which is hard to work with horses unless well drained.

GENERAL CONDITIONS OF RUN-OFF.

The run-off from the streams in this area results principally from direct rainfall, melting snow, and melting glaciers. In view of the large rainfall, the excellent forest cover, and the glacial areas, the

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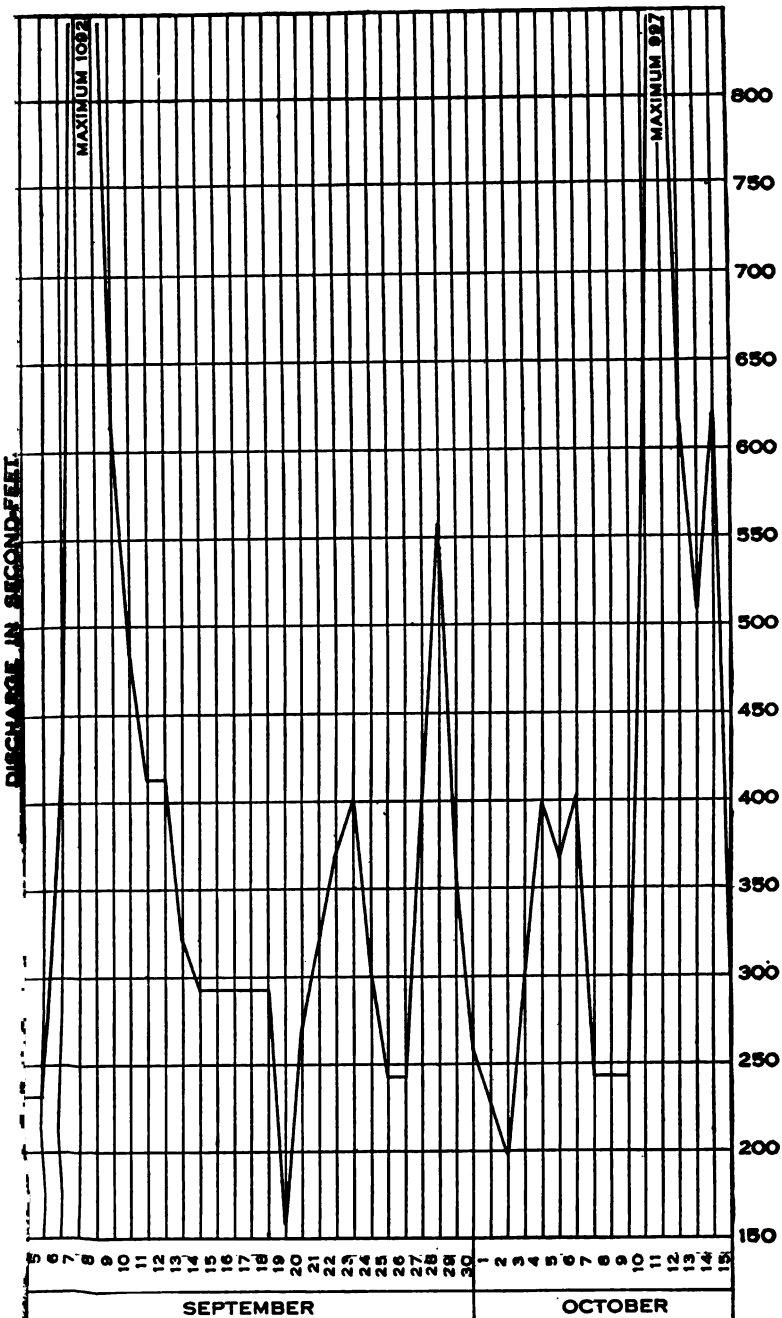

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general deduction would be that this section should have many large streams with an abundant and well-sustained run-off. This, however, is not the case, as the catchment areas are small, and although the total yield per square mile is considerable, the streams are not large and they fluctuate very rapidly.

The forest effects are principally offset by the deep slopes and shallow soil, which afford but little ground storage. The streams respond very quickly to the rainfall and their volume drops with equal quickness as soon as it ceases to rain. Frequently they are reduced from a maximum to a minimum flow within a few days. This is illustrated in the hydrograph of Porcupine Creek near Haines, in the northern part of the area (Pl. XXII). This stream has a drainage basin of 34 square miles and heads in a large glacial area.

In many places, owing to the steep slopes, there are no well-defined streams but instead the water runs down the mountain side in many small channels, some on the surface and others between the soil and the rock. In some of the developments the water is obtained by contour ditches which bring the water together from these streams.

Most of the large glaciers terminate at elevations but little above sea level and are therefore practically of small value as a source of water supply for the development of power. The smaller glaciers are beneficial only during the summer months, as their water is cut off early in the fall by the frosts. It is probable that many of the extreme variations in the glacier-fed streams are due to the making and breaking of ice jams which raise and hold back the water.

The streams which head in lakes have a much better sustained flow and are practically the only ones in the area which are of much value for power, as any large development must depend on storage both for the winter months and during dry parts of the summer.

The principal defect in the water supply, so far as the production of power is concerned, is the extreme low flow during the winter months. On the smaller streams, which have no storage, there is practically no flow in winter, and even on the streams having lake storage the flow is extremely low, as shown in the records for Turner River (fig. 6), which empties into Taku Inlet near Juneau. This stream has a drainage area of 66 square miles and heads in Turner Lake, which offers excellent facilities for storage. A portion of the area is also covered with glaciers. The scantiness of the winter flow is due largely to the meager amount of storage capacity in the ground, which freezes to bedrock, thus holding back the water.

INDUSTRIAL CONDITIONS.

With the exception of a few towns along the shore and scattered mining camps and fisheries, southeastern Alaska is very sparsely settled. The only ready means of transportation is by boat. Aside

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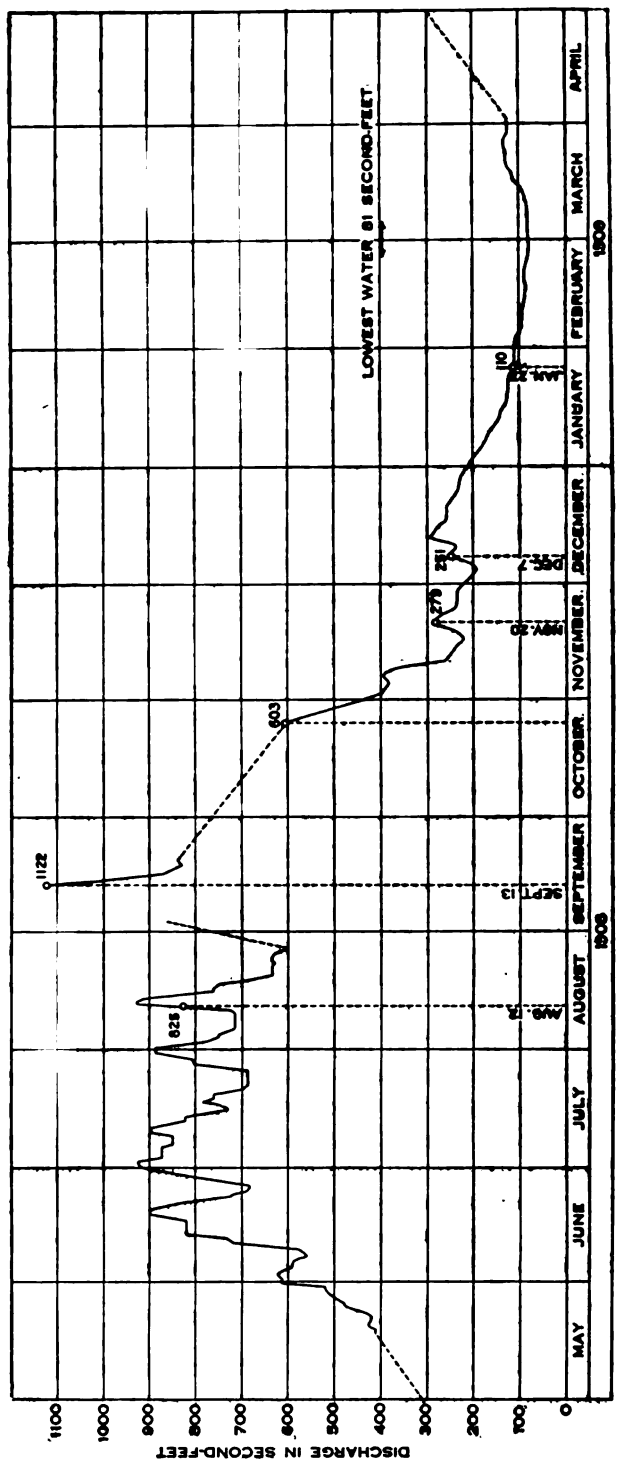

FIGURE 6.—Hydrograph of Turner River. From record furnished by Alaska Treadwell Gold Mining Co.

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from the regular steamers which run from Seattle and other ports, each town has a local service connecting it with adjoining towns and camps by gasoline launches.

There are practically no roads and the country back from the shore line is almost inaccessible. The building of Government roads, which is now under way, will be a great help to the development of the country.

The two well-developed industries are fishing and mining. The larger part of the fishing is for the salmon canneries. An icing plant has just been established at Ketchikan. The mines are principally quartz mines, yielding gold and copper.

Next to fishing and mining comes lumbering, which at present is but little developed and is confined to shingle mills and a few small sawmills that meet the local demands. Agriculture, owing to the small amount of suitable land available, will always be of very minor importance.

The success and future development of both the mining and the lumbering interests depend wholly on their ability to get cheap power. Most of the mines so far opened have been in the Juneau belt and are in ore of low grade, large amounts of which must be cheaply handled in order to make them profitable. The best paying mines owe their successful operation to the presence of cheap power in their immediate vicinity, and their future development will depend on the procuring of further cheap power. This is a vital question with the older companies, and they are investigating every possible source of power. The fishing industry demands only a small amount of power during the canning season. This can readily be obtained at small expense in the vicinity of the plants.

In developing the timber resources it will be possible to produce cheap steam power by the use of sawmill waste as fuel. The ultimate development, however, for both lumber and pulp will be through the establishment of mills at accessible power sites.

The future development of electrochemical processes may open a new industry for this region. In its present stage, however, there is no field in Alaska for this industry.

Practically the whole area here considered is included in the Tongass National Forest, and therefore the conditions governing the national forests will, in a large measure, regulate the development of the timber and other resources of this country.

POWER POSSIBILITIES.

As shown in the subjoined table there were 102 water wheels in southeastern Alaska in 1908, developing 15,319 horsepower. This table is based on a special water-power census taken by the United

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States Census Bureau, and the amounts are made up from statements received from power owners in the various sections. These figures have not been verified, but it is believed that they are somewhat large, as they probably give the maximum development, and this can be maintained only during a small portion of the year. Most of the plants have but little power during the winter months.

In considering the development of the water powers in southeastern Alaska the possibility of developing power from lignite and coal deposits in that region must be taken into account. When these deposits are opened, fuel will probably be available at a comparatively low cost on account of the ease of water transportation, and steam power may be produced much more cheaply and will be more reliable than the water power.

A great drawback to water-power development in this region is the difficulty of transmission. The country, as already stated, is cut by numerous channels, has a rough topography, and is covered with dense forests. Therefore transmission lines are difficult and expensive to construct, and this practically prohibits development at sites where the power can not be utilized at the point of development. In view of these difficulties, the possibilities at the present time for large power development in southeastern Alaska are not great, and such projects should be closely scrutinized as to their feasibility both from an engineer's standpoint and from that of an investor.

The opening of new mining districts and the development of the timber interests in this region will create a more widely distributed demand for power and enable the utilization of sites which at the present time can not be considered as available. As already stated, the success of any large water-power development, to be run during the entire year, will depend on the possibility of adequate storage. The meager topographic data available indicate that there are probably many lakes throughout the region which will offer excellent storage facilities.

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Developed water power in southeastern Alaska, 1908.

Owner.	Location of plant.	Number of wheels.	Horse-power.	Character of industry.
Porcupine Gold Mining Co	Porcupine Creek	2	50	Placer mining.
Columbia Canning Co	Haines	3	70	Cannery.
Nugget Creek Mining Co	do	2	24	Mining.
Columbia Canning Co	Leonard Creek	3	25	Salmon cannery.
Shakan Salmon Co	Shakan Creek	4	150	Do.
Cahoon Creek Placer Co	McKinley Creek	2	100	Placer mining.
Union Iron Works	Gold Creek	1	8	Machine shop.
Hydraulic Pipe and Boiler Works	Juneau	1	8	Pipe and boiler works.
Finn & Young	Shakan	1	25	
William Duncan	Metlakatla	2	53	Sawmill and salmon cannery.
R. G. Ketchum	Kupreanof Island	1	50	Barrel factory.
Alaska Industrial Co	Jumbo Creek	1	150	
Do	Sulzer	1	30	Mining.
American Gold Mining Co	Sheep Creek	3	80	Do.
Yukon Publishing Co	Skagway	1	3	Newspaper.
Home Power Co	Lake Dewey	1	125	Light and power.
New England Fish Co	Lake Whitman and Coal Creek.	2	1,100	Fish freezing and ice making.
J. P. Jorgenson & Co	Juneau	1	25	Lumber.
Ebner Gold Mining Co	Gold Creek	4	4,000	Quartz mining.
Alaska Perseverance Mining Co	Silverbow Basin	8	880	Mining.
Alaska-Juneau Gold Mining Co	do	2	500	Do.
F. H. Partridge	Hoonah	2	15	Sawmill.
Alaska Copper Co	Lake Creek	4	300	Smelter and sawmill.
A. Murray	Douglas	2	5	Wood turning, etc.
Juneau Iron Works	Juneau	1	6	General repairs.
Treadwell group	Douglas Island	37	6,297	Gold mining.
Citizens' Light, Power and Water Co.	Ketchikan Creek	2	240	Do.
Alaska Electric Light and Power Co.	Gold Creek	5	1,000	Do.
Chichagof Gold Mining Co	Clay Bay	1	150	Do.
		99	15,319	

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WATER RESOURCES OF HAWAII

1913

BY

G. K. LARRISON

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WATER RESOURCES OF HAWAII, 1913.

By G. K. Larrison.

AUTHORITY FOR INVESTIGATIONS.

This volume contains results of measurements of the flow of certain streams and ditches and rainfall records of the Territory of Hawaii made during the calendar year 1913. The investigations leading to the report were made by the United States Geological Survey in cooperation with the Territory of Hawaii, under the general sanction of the organic law of the Survey (Stat. L., vol. 20, p. 394), which contains the following paragraph:

Provided, That this officer [the Director] shall have the direction of the geological survey and the classification of public lands and examination of the geological structure, mineral resources, and products of the national domain.

As water is the most abundant and most valuable of the minerals, the investigation of water resources is authorized under the provision for examining mineral resources. The work has been supported since the fiscal year ending June 30, 1895, by appropriations in successive sundry civil bills passed by Congress under the following item:

For gaging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells, and for the preparation of reports upon the best methods of utilizing the water resources.

The legislature of the Territory of Hawaii approved on March 22, 1909, "An act to promote the conservation and development of the natural resources of the Territory," which provided in substance as follows: A special tax of 2 per cent shall be levied, assessed, and collected annually on all incomes in excess of $4,000; and all amounts so collected shall constitute a special fund to be expended only for the encouragement of immigration and the conservation of natural resources in the proportion of three-fourths for immigration and one-fourth for conservation. The conservation fund shall be used for the development, conservation, improvement, and utilization of the natural resources, and shall be available for expenditure at such times and in such manner as a board of three persons appointed in accordance with section 80 of the organic act shall, with the approval of the governor, determine.

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An act of April 26, 1911, amended the original act so as to extend it until December 31, 1913.

On April 4, 1913, the governor of the Territory of Hawaii approved the following acts providing (act 56) for the creation and maintenance of a division of hydrography under the board of agriculture and forestry, and (act 57) appropriating the revenues from water licenses for the use of the board of commissioners of agriculture and forestry toward forest protection and hydrographic surveying.

Section 1 of act 56 reads:

The board of agriculture and forestry is hereby authorized to create and maintain a division of hydrography for the investigation and determination of the water resources of the Territory by the gaging of streams and rainfall and other means, in cooperation with the United States Geological Survey or otherwise, and in furtherance thereof to take over and exercise the functions of the Territory in the conduct of the present hydrographic survey of the Territory.

Section 2 provides that this act shall take effect on July 1, 1913.

Section 1 of act 57 reads:

All revenues derived from water licenses, issued by the Territory, during the period beginning July 1, 1913, and ending June 30, 1915, whether by way of rentals or otherwise, shall constitute and be held as a special fund in the treasury of the Territory to be disbursed on warrants of the auditor issued on approved vouchers of the president of the board of commissioners of agriculture and forestry. Such moneys shall be apportioned and applied from time to time by the board of commissioners of agriculture and forestry, acting with the approval of the governor, equally between the division of forestry and the division of hydrography to the following general purposes, and not otherwise:

1. For the protection of forest reservations, established or set apart according to law, against damage by fire, animals, and otherwise by means of fences and any other means whatsoever, and for the expenditures of the division of forestry.

2. For the development and maintenance of the hydrographic survey throughout the Territory.

Each voucher against said fund shall designate the general purpose for which it is drawn.

Section 2 provides that this act also shall take effect on July 1, 1913.

COOPERATION.

Under the authority conferred by the Federal and Territorial legislation, the Director of the United States Geological Survey and the governor of the Territory of Hawaii entered into a cooperative agreement, dating from July 1, 1910, for "the gaging of streams and the determination of the water supply of the Territory of Hawaii." [1]

The principal features of this agreement are:

1. The United States Geological Survey assumes the responsibility of gathering, analyzing, and publishing the data.

2. During the progress of the work all notes, maps, and data gathered as a result of field studies are at all times open to inspection by

[1] The United States Geological Survey is also cooperating with the Territory of Hawaii in mapping the several islands. The whole of the island of Kauai and a part of the island of Hawaii have been mapped.

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the representative of the Territory, and if they are not entirely satisfactory the agreement can be terminated.

3. Accounts for payment of salaries, travel, and subsistence, supplies, or other expenses necessary to the completion of the work shall be rendered in the manner required by the laws and regulations of the contracting parties, and vouchers shall be preferred to either party for payment according as it may be convenient or according to the balance remaining in the respective allotments.

4. The cost of publication is borne entirely by the Geological Survey.

The Territory of Hawaii was represented in the cooperation by the board of conservation appointed by Gov. Walter F. Frear, and consisted of J. P. Cooke (chairman), J. W. Caldwell, and E. V. Wilcox, until June 30, 1913. After this date the Territory was represented by the board of commissioners of agriculture and forestry, consisting of W. M. Giffard (president and executive officer), A. Waterhouse, J. M. Dowsett, H. M. von Holt, and A. H. Rice.

SCOPE OF WORK.

The investigations of stream flow in the Territory are not complete, nor do they include all the streams that might advantageously be studied. They include, however, as many of the streams and ditches on the four larger islands as the available appropriations would allow. It is essential that records of stream flow should be kept during a period of years long enough to determine within reasonable limits the range of flow from the maximum to the minimum. The length of such a period manifestly varies for different streams. Experience has shown that the records should be kept from 20 to 30 years.

In the performance of this work an effort is made to reach the highest degree of precision possible with a rational expenditure of time and money. In all engineering work there is a point beyond which refinement is needless and wasteful, and this statement applies with especial force to stream-measurement work in Hawaii. It has been found, however, that it is possible to obtain data which are sufficiently accurate, although many of those presented in this report are for periods too short to admit of definite conclusions.

FIELD METHODS OF MEASURING STREAM FLOW.

BASE DATA.

In making plans for power, irrigation, municipal water supply, and other projects involving the use of water from surface streams it is necessary to have data from which both the total flow of the stream and its distribution from day to day throughout the year can be obtained. The data necessary for obtaining such information are

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daily gage heights, which give the fluctuations of rise and fall of the stream, and measurements of discharge at various stages, from which a rating curve and table can be prepared, giving the discharge for any stage. Such a rating is possible from the fact that so long as the conditions at the controlling point in the stream remain the same there will be approximately the same discharge for any given gage height.

The determination of a discharge is termed a discharge measurement, and points at which discharge measurements are made and records of daily fluctuations of stage are kept for determining the daily flow are termed gaging stations.

Gaging stations may be divided into two classes, known as weir stations and velocity-area stations. At weir stations the head of water on the crest of the weir is measured and the discharge computed by means of a formula. The discharge at velocity-area stations is obtained by measuring the velocity of the current and the area of the cross-section, the product of the two giving the discharge.

The data presented in this paper were collected at both weir and velocity-area stations.

WEIR MEASUREMENTS.

Unquestionably a weir properly constructed and of a type for which accurate coefficients have been determined is one of the most convenient and reliable means of measuring small quantities of water. In practice, however, weirs rarely conform to the requirements imposed by the experimenter who derived the coefficients. If the crest of the weir is sharp and clean and sufficiently high above the bottom of the leading channel and the end contractions are complete and the velocity of approach is wanting, or negligibly small, andif the head on crest is measured at a distance back of the overfall of at least the weir crest length, the Francis formula will give good results. On the other hand, if these essential conditions are not complied with, especially if the velocity of approach is considerable and the contractions are imperfect, the Francis formula will not give accurate results. This is particularly true if the weir is improperly constructed and there is leakage around and under it, as is so frequently the case in practice.

Observations made on various types of weirs in Hawaii show that of the weirs in use in the Territory not all are giving accurate results. If the error is known so that corrections can be made the trouble is largely mitigated, but faulty weir records are too often accepted without investigation as to their accuracy.

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VELOCITY-AREA METHOD.

The velocity-area method of measurement consists of determining the mean or average velocity of the water past a given cross-section area. The area of the cross section at right angles to the direction of flow is determined by soundings which are taken at such distances apart as will develop the contour of the stream bed. The depths are recorded and also their distances from some arbitrarily chosen initial point on one side of the stream.

The method of making the soundings depends on the size and stage of the stream. On ditches and small streams, where the depths and velocities are not large, a graduated rod may be used to advantage; on large streams, which must be measured from bridges or cables, a lead weight and sounding line must be used. The weights are of different sizes—6½, 10, or 15 pounds—according to the swiftness of the current, and are torpedo shaped, so as to offer as little resistance as possible to the moving water.

On streams with beds which are permanent or nearly so a standard cross section is usually constructed from careful soundings and referred to the zero of the gage, so that the depths for any stage can be found by adding the gage height at that stage to the depths below the zero of the gage. This method is especially useful at high stages, when it is difficult to make accurate soundings.

After the cross-section area of the stream has been measured by soundings and horizontal distances, the velocity is determined at a number of points. These measurements of velocity should be made at frequent intervals across the stream and close enough to take account of any abrupt change in the velocity. For convenience, the velocities are usually observed in the same verticals at which soundings are made. On some streams fairly good measurements of velocities may be made by means of subsurface floats. This method is applicable, however, only to channels of uniform cross-section area over a considerable distance and is very unsatisfactory for use on natural streams like those of Hawaii.[1]

The velocity of flow is best determined by the current meter, which is a form of water wheel actuated by the current, and of such size and shape that it can easily be placed at any point in the stream.

The new type of penta-recording current meter consists of six cups attached to a vertical shaft which revolves on a conical hardened-steel point when immersed in moving water. The revolutions are indicated electrically or acoustically. The rating, or relation between the velocity of moving water and the revolutions of the wheel, is determined for each meter by drawing it through still water for a given distance at different speeds and noting the number of revolu-

[1] Further information regarding the float method is given in Water-Supply Paper 95 and in textbooks on stream flow.

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tions for each run. From these data a rating table is prepared which gives the velocity in feet per second of moving water for any number of revolutions in a given time interval. The ratio of revolutions per second to velocity of flow in feet per second is very nearly a constant for all speeds and is approximately 0.45.

Three classes of methods of measuring velocity with current meters are in general use—multiple-point, single-point, and integration.

The two principal multiple-point methods in general use are the vertical velocity curve and 0.2 and 0.8 depth.

In the vertical velocity-curve method a series of velocity determinations are made in each vertical at regular intervals, usually about 10 to 20 per cent of the depth apart. By plotting these velocities as abscissas and their depths as ordinates and drawing a smooth curve among the resulting points, the vertical velocity curve is developed. This curve shows graphically the magnitude and changes in velocity from the surface to the bottom of the stream. The mean velocity in the vertical is then obtained by dividing the area bounded by this velocity curve and its axis by the depth. This method of obtaining the mean velocity in the vertical is probably the best known, but on account of the length of time required to make a complete measurement its use is largely limited to the determination of coefficients for purposes of comparison.

In the second multiple-point method the meter is held successively at 0.2 and 0.8 depth, and the mean of the velocities at these two points is taken as the mean velocity for that vertical. On the assumption that the vertical velocity curve is a common parabola with horizontal axis, the mean of velocities at 0.22 and 0.79 depth will give (closely) the mean velocity in the vertical. Actual observations under a wide range of conditions show that this multiple-point method gives the mean velocity very closely for open-water conditions and that in a completed measurement it seldom varies as much as 1 per cent from the value given by the vertical velocity-curve method. It is very extensively used in the regular practice of the United States Geological Survey.

The single-point method consists in holding the meter either at the depth of the thread of mean velocity or at an arbitrary depth for which the coefficient for reducing to mean velocity has been determined or must be assumed.

Extensive experiments by means of vertical velocity curves show that the thread of mean velocity generally occurs between 0.5 and 0.7 total depth. In general practice the thread of mean velocity is considered to be at 0.6 depth, and at this point the meter is held in most of the measurements made by the single-point method. A large number of vertical velocity curve measurements, taken on many streams and under varying conditions, show that the average coefficient for reducing the velocity obtained at 0.6 depth to mean

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velocity is practically unity. The variation of the coefficient from unity in individual cases is, however, greater than in the 0.2 and 0.8 method and the general results are not as satisfactory.

In the other principal single-point method the meter is held near the surface, usually 1 foot below, or low enough to be out of the effect of the wind of other disturbing influences. This is known as the subsurface method. The coefficient for reducing the velocity taken at the subsurface to the mean has been found to be in general from about 0.85 to 0.95, depending on the stage, velocity, and channel conditions. The higher the stage the larger the coefficient. This method is especially adapted for flood measurements, or for measurements when the velocity is so great that the meter can not be kept in the correct position for the other methods.

The vertical integration method consists in moving the meter at a slow but uniform speed from the surface to the bottom and back again to the surface and noting the number of revolutions and the time taken in the operation. This method has the advantage that the velocity at each point of the vertical is measured twice. It is useful as a check on the point methods. In using the Price meter great care should be taken that the vertical movement of the meter is not rapid enough to vitiate the accuracy of the resulting velocity determination.

In practical work on rough streams, such as exist in Hawaii, the meter should be held at 0.6 depth for depths of 1 foot or less. For greater depths the meter should be held at two points in the vertical, 0.2 and 0.8 from the surface.

When the mean velocities in the different verticals have been found, the average of two adjacent means is taken as the mean velocity for that individual section. The area of the section is computed by multiplying the width of the section by the mean depth. The discharge of each section is then the product of the area multiplied by the mean velocity, and the total discharge of the stream results from summing up the discharge of the individual sections. In practice the work is tabulated in such a way as to render the computation very simple.[1]

Current meter measurements are not practicable where there are eddies, cross currents, swirls, or passages for the water underneath stones. It is usually possible, however, to improve the channel by removing bowlders and rocks, so that a satisfactory measuring section may be obtained, even on rough, steep streams such as exist in Hawaii.

Three kinds of velocity-area gaging stations are in general use in Hawaii, according to the means provided for making the observations of depth and velocity. They are wading, bridge, and cable stations.

[1] For a discussion of methods of computing the discharge of a stream see Engineering News, June 25, 1908.

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A wading station is one at which measurements are made only by wading; that is, no means exist for getting above the water at any stage except by wading. Such stations are usually on ditches or wide, shallow streams, which do not fluctuate greatly in flow. Frequently, however, measurements are made at low stages by wading, even though other means exist for making measurements at higher stages.

A bridge station is one at which the meter is used from a bridge. In some places highway or other bridges are available from which to make measurements, but generally they are not at the right place on the stream. Special bridges are then built.

A cable station is one at which measurements are made from a cable spanning the stream. Cable stations are used on large streams, such as Hanapepe, Wailua, and Hanalei rivers on the island of Kauai, and Wailuku River on the island of Hawaii. The cable supports the car from which a man works above the water. Distances are marked off on the cable itself or on a small auxiliary cable stretched taut above it.

A suitable place for a gaging station having been selected, a staff gage is set in the edge of the stream, either vertical or inclined, but graduated into tenths, half-tenths, or hundredths of feet vertically. The gage is securely fastened to rocks or trees to prevent displacement by floods and is so placed that the zero, or reference datum, is well below extreme low water. The datum is also referred to a permanent bench mark as an additional precaution. A water-stage recorder is then installed or an observer is engaged to record the heights of water morning and evening, and the mean of the two readings is used as the mean gage height for the day. Owing to the rapid rise and fall of most of the streams in Hawaii, two gage-height readings a day will not as a rule give a true mean for the 24 hours. For this reason, and also owing to the fact that many of the gaging stations are necessarily situated in the mountains at points remote from all habitations and difficult of access, it has generally been found necessary to use water-stage recorders. These instruments are of various types, some requiring weekly visits and others operating for a month without attention.

The essential features of water-stage recorders comprise a float free to rise and fall with fluctuations of the water surface, a device for transferring the motion of the float to the record sheet (either directly or through a reducing mechanism), the recording device, and the clock. The instruments may be designed for any range of stage. Those used by the United States Geological Survey in Hawaii are designed for ranges up to as high as 36 feet, but so far those having a 20-foot range have been found to be sufficient for any stage.

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DEFINITION OF TERMS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated more or less definitely with a certain class of work. These terms may be divided into two groups: (1) Those which represent a rate of flow, as "second-feet"; "gallons per minute," "gallons per 24 hours," "miner's inches," and "run-off in second-feet per square mile," and (2) those which represent the actual quantity of water, as "run-off in depth in inches," "million gallons," and "acre-feet." They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second, and is the unit for the rate of discharge of water flowing in a stream 1 square foot in cross section at a rate of 1 foot per second. It is generally adopted as the fundamental unit in the measurement of flowing water and is the "natural" unit, as the foot and the second are the units used in making the physical determinations. Other units may be computed from this by the use of factors given in the table of equivalents.

"Gallons per minute" is generally used in connection with pumping and city water supply, the United States gallon of 231 cubic inches being the unit of quantity and 1 minute the unit of time.

The "miner's inch" is the unit for the rate of discharge of water that passes through an orifice 1 inch square under a head which varies locally. It is commonly used by miners and irrigators throughout the West, and is defined by statutes in each State in which it is used.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

An "acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. The term is commonly used in connection with storage for irrigation.

In the Territory of Hawaii a unit commonly used in connection with the measurement of water is the "million gallons." This is used with two meanings—(1) to indicate a rate of flow and (2) to express an actual quantity of water. In the former sense "million gallons per 24 hours" is inferred, 1,000,000 gallons being taken as the unit of quantity and 24 hours as the unit of time. With this meaning the term is generally used in connection with pumping and irrigation. In the

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latter sense "million gallons" as an absolute quantity is used in the measurement of storage capacities of reservoirs.

The following convenient approximate relations exist between second-feet, million gallons per 24 hours, and acre-feet: 1 second-foot flowing 24 hours equals about 2 acre-feet; 1,000,000 gallons equals about 3 acre-feet; and 1 second-foot equals approximately two-thirds million gallons per 24 hours.

"Man's water" is an irrigator's terms also in common use in Hawaii. It signifies the amount of water that one irrigator can properly handle in the field. It varies greatly, being dependent upon the condition of the furrows, the age of the crop, and the skill and individuality of the irrigator.

CONVENIENT EQUIVALENTS.

The following is a list of convenient equivalents for use in hydraulic computations:

Table for converting discharge in second-feet into run-off in acre-feet.

Discharge (second-feet).	Run-off (acre-feet).				
	1 day.	28 days.	29 days.	30 days.	31 days.
1	1.983	55.54	57.52	59.50	61.49
2	3.967	111.1	115.0	119.0	123.0
3	5.950	166.6	172.6	178.5	184.5
4	7.934	222.1	230.1	238.0	246.0
5	9.917	277.7	287.6	297.5	307.4
6	11.90	333.2	345.1	357.0	368.9
7	13.88	388.8	402.6	416.5	430.4
8	15.87	444.3	460.2	476.0	491.9
9	17.85	499.8	517.7	535.5	553.4

NOTE.—For part of a month multiply values for one day by the number of days.

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,317 gallons for one day.

1 second-foot for one year (365 days) covers 1 square mile 1.131 feet or 13.572 inches deep.

1 second-foot for one year (365 days) equals 31,536,000 cubic feet.

1 second-foot for one year (365 days) equals 724 acre-feet.

1 second-foot equals about 1 acre-inch per hour.

1 second-foot for one day covers 1 square mile 0.03719 inch deep.

1 second-foot for one day equals 1.983 acre-feet.

1,000,000 United States gallons per day equals 1.55 second-feet.

1,000,000 United States gallons equal 3.07 acre-feet.

1,000,000 cubic feet equals 22.95 acre-feet.

1 acre-foot equals 325,850 gallons.

1 inch deep on 1 square mile equals 2,323,200 cubic feet.

1 inch deep on 1 square mile equals 0.0737 second-foot per year.

1 foot equals 0.3048 meter.

1 mile equals 1.60935 kilometers.

1 mile equals 5,280 feet.

1 acre equals 0.4047 hectare.

1 acre equals 43,560 square feet.

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1 acre equals 209 feet square, nearly.
1 square mile equals 2.59 square kilometers.
1 cubic foot equals 0.0283 cubic meter.
1 cubic foot equals 7.48 gallons.
1 cubic foot of water weighs 62.5 pounds.
1 cubic meter per minute equals 0.5886 second-foot.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 76.0 kilogram-meters per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.80 feet.
1½ horsepower equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{11}$ = net horsepower on water wheel realizing 80 per cent of theoretical power.

OFFICE METHODS OF COMPUTING AND STUDYING DISCHARGE AND RUN-OFF.

At the end of each year the field or base data for current-meter gaging stations, consisting of water-stage record sheets, daily gage heights, discharge measurements, and notes from observers' books are assembled. The measurements are plotted on cross-section paper and rating curves are drawn wherever feasible. The rating tables prepared from these curves are then applied to the tables of daily gage heights to obtain the daily discharge, and from these applications the tables of monthly discharge and run-off are computed.

Rating curves are drawn and studied with special reference to the class of channels which they represent. The discharge measurements for all classes of stations, when plotted with gage heights in feet as ordinates and discharges in second-feet as abscissas, define rating curves which are generally more or less parabolic in form. For many stations curves of area in square feet and mean velocity in feet per second are also constructed to the same scale of ordinates as the discharge curve. These are used mainly to extend the discharge curves beyond the limits of the plotted discharge measurements, to check the form of the discharge curve, and to determine and eliminate erroneous measurements.

For every rating table the following assumptions are made for the period of application of the table: (*a*) That the discharge is a function of and increases gradually with the stage; (*b*) that the discharge is the same whenever the stream is at a given stage, and hence such changes in conditions of flow as may have occurred during the period of application are either compensating or negligible, except that the rating, as stated in the footnote of each table, is not applicable for periods during which the channel was obstructed; (*c*) that the increased and decreased discharge due to change of slope on rising and falling stages is either negligible or compensating.

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As already stated, the gaging stations may be divided into several classes, as indicated in the following paragraphs:

The stations of class 1 represent the most favorable conditions for an accurate rating and are also the most economical to maintain. The bed of the stream is usually composed of rock and is not subject to the deposit of sediment and loose material. This class includes also many stations located in a pool below which is a permanent rocky riffle that controls the flow like a weir. Provided the control is sufficiently high and close to the gage to prevent cut and fill at the gaging point from materially affecting the slope of the water surface, the gage height will for all practical purposes be a true index of the discharge. Discharge measurements made at such stations usually plot within 2 or 3 per cent of the mean discharge curve, and the rating developed from that curve represents a very high degree of accuracy.

Class 2 comprises mainly stations on rough, mountainous streams with steep slopes. The beds of such streams are, as a rule, comparatively permanent during low and medium stages, and when the flow is sufficiently well defined by an adequate number of discharge measurements before and after each flood the stations of this class give nearly as good results as those of class 1. As it is seldom possible to make measurements covering the time of change at flood stage, the assumption is often made that the curves before and after the flood converged to a common point at the highest gage height recorded during the flood. Hence the only uncertain period occurs during the period of actual change in conditions of flow.

Class 3 includes those stations where the stream bed is of a shifting character, or the controlling section below the gage frequently changes owing to cutting out by the current and the filling in of sand, gravel, and drift. In some cases in Hawaii changes are caused by the growth of vegetation in the stream bed. No absolute rule can be laid down for stations of this class. Each rating curve must be constructed mainly on the basis of the measurements of the current year, the engineer being guided largely by the history of the station and the following general law: If all measurements ever made at a station of this class are plotted on cross-section paper, they will define a mean curve which may be called a standard curve. It has been found in practice that if after a change caused by high stage a relatively constant condition of flow occurs at medium and low stages, all measurements made after the change will plot on a smooth curve which is practically parallel to the standard curve with respect to ordinates or gage heights. This law of the parallelism of rating curves is the fundamental basis of all ratings and estimates at stations with semipermanent and shifting channels. It is not absolutely correct, but, with few exceptions, answers all the practical requirements

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of estimates made at low and medium stages after a change at a high stage. This law appears to hold equally true whether the change occurs at the measuring section or at some controlling point below. The change is, of course, fundamentally due to change in the channel caused by cut or fill, or both, at or near the measuring section. For all except small streams the changes in section usually occur at the bottom. The following simple but typical examples illustrate this law:

(*a*) If 0.5 foot of planking were to be nailed on the bottom of a well-rated wooden flume of rectangular section, there would result, other conditions of flow being equal, new curves of discharge, area, and velocity, each plotting 0.5 foot above the original curves when referred to the original gage. In other words, this condition would be analogous to a uniform fill or cut in a river channel which either reduces or increases all three values of discharge, area, and velocity for any gage height. In practice, however, such ideal conditions rarely exist.

(*b*) In the case of a cut or fill at the measuring section, there is a marked tendency toward decrease or increase, respectively, of the velocity. In other words, the velocity has a compensating effect, and if the compensation is exact at all stages the discharge at a given stage will be the same under both the new and the old conditions.

(*c*) In the case of uniform change along the crest of a weir or rocky control, the area curve will remain the same as before the change, and it can be shown that here again the change in velocity curve is such that it will produce a new discharge curve essentially parallel to the original discharge curve with respect to their ordinates.

Of course, in actual practice such simple changes of section do not occur. The changes are complicated and lack uniformity, a cut at one place being largely offset by a fill at another, and vice versa. If these changes are very radical and involve large percentages of the total area—as, for example, on small streams—there may result a wide departure from the law of parallelism of rating curves. In complicated changes of section the corresponding changes in velocity which tend to produce a new parallel discharge curve may interfere with each other materially, causing eddies, boils, backwater, and radical changes in slope. In such extreme conditions, however, the measuring section would more properly fall under class 4 and would require very frequent measurements of discharge. Special stress is laid on the fact that in the lack of other data to the contrary the utilization of this law will yield the most probable results.

Slight changes at low or medium stages of an oscillating character are usually averaged by a mean curve drawn among them parallel to the standard curve, and if the individual measurements do not

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vary more than 5 per cent from the rating curve the results are considered good for stations of this class.

Class 4 comprises stations on streams that have soft, muddy, or sandy beds. Good results can be obtained from such sections only by frequent discharge measurements, the frequency ranging from a measurement every two or three weeks to a measurement every day, according to the rate of diurnal change in conditions of flow. These measurements are plotted and a mean or standard curve drawn among them. It is assumed that there is a different rating curve for every day of the year and that this rating is parallel to the standard curve with respect to their ordinates. On the day of a measurement the rating curve for that day passes through that measurement. For days between successive measurements it is assumed that the rate of change is uniform, and hence the ratings for the intervening days are equally spaced between the ratings passing through the two measurements. This method must be modified or abandoned altogether under special conditions. Personal judgment and a knowledge of the conditions involved can alone dictate the course to pursue in such cases.

The computations have, as a rule, been carried to three significant figures. Computation machines and the 20-inch slide rule have been generally used. All computations are carefully checked.

After the computations have been completed they are entered in tables and carefully studied and intercompared to eliminate or account for all gross errors so far as possible. Missing periods are filled in, so far as feasible, by means of comparison with records for adjacent streams. The attempt is made to complete years or periods of discharge, thus eliminating fragmentary and disjointed records. Full notes accompanying such estimates follow the daily and monthly discharge tables.

EXPLANATION OF TABLES.

For each regular current-meter gaging station are given in general the following data: Description of station, list of discharge measurements, table of daily discharge, table of monthly and yearly discharge, and run-off in acre-feet.

All rates of flow are expressed as second-feet, because distances and depths are measured in feet, and velocities in feet per second. The flow is thus obtained in cubic feet per second, or more briefly in "second-feet." The term "million gallons per 24 hours" is not used except in a few tables where data have been furnished in these units by private cooperations. "Million gallons per 24 hours" is not a primary but a derived unit. To convert second-feet into million gallons per 24 hours multiply by 0.646.

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In addition to statements regarding the location and installation of current-meter stations, the descriptions give information in regard to any conditions which may affect the constancy of the relation of gage height to discharge, covering such points as shifting channels and backwater; also information regarding diversions which decrease the total flow at the measuring section. Statements are also made regarding the accuracy and reliability of the data.

The discharge-measurement table gives the results of the discharge measurements made during the year, including the date, name of hydrographer, gage height, and discharge in second-feet.

The discharge measurements and gage heights are the base data from which rating tables, daily discharge tables, and monthly discharge tables are computed.

The table of daily discharge gives the discharge in second-feet corresponding to the observed gage height as determined from the rating table, the number of significant figures used varying with the size of the discharge.

In the table of monthly discharge the column headed "Maximum" gives the mean flow, as determined from the rating table, for the day when the mean gage height was highest. As the gage height is the mean for the day, it does not indicate correctly the stage when the water surface was at crest height and the corresponding discharge was consequently larger than given in the maximum column. Likewise in the column of "Minimum" the quantity given is the mean flow for the day when the mean gage height was lowest. The column headed "Mean" gives the average flow in cubic feet for each second during the month. The "run-off in acre-feet" given in the column under that head is computed from the mean discharge in second-feet.

ACCURACY OF FIELD DATA AND COMPUTED RESULTS.

The accuracy of stream-flow data depends (1) on permanence of the relation between discharge and stage, and (2) on the accuracy of observations of stage, measurements of discharge, and interpretation of data.

The accuracy column in the monthly discharge table does not apply to the maximum or minimum nor to any individual day, but to the monthly mean. It is based on the accuracy of the rating, the probable reliability of the observer, the number of gage readings per day, the range of the fluctuation in stage, and knowledge of local conditions. In this column, A indicates that the mean monthly flow is probably accurate within 5 per cent; B, within 10 per cent; C, within 15 per cent; D, within 25 per cent. Special conditions are covered by footnotes.

It should be borne in mind that the observations in each succeeding year may be expected to throw new light on data already collected and published.

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DIVISION OF WORK.

On account of the isolation of the different islands of the Territory an engineer or employee was assigned to take charge of the field work on each of the four largest islands, with temporary headquarters on those islands.

Persons in charge of field work.

Island.	In charge.	Headquarters.
Oahu	G. K. Larrison, district engineer	Honolulu (permanent).
	J. C. Dort, assistant engineer	Do.
Kauai	W. V. Hardy, field assistant	Waimea (temporary).
Maui	C. T. Bailey, assistant engineer	Wailuku (temporary).
Hawaii	E. O. Christiansen, assistant engineer	Hilo [a] (temporary).

[a] Discontinued July 18, 1913.

The ratings, applications, and computations were made by J. C. Dort, C. T. Bailey, W. V. Hardy, E. O. Christiansen, Howard Kimble, H. A. R. Austin, E. E. Goo, G. R. White, John Kaheaku, S. W. Dort, H. M. Kennedy, and R. M. S. Goo. The report was edited by Mrs. B. D. Wood.

GAGING STATIONS MAINTAINED IN HAWAII.

The following list comprises the gaging stations maintained in Hawaii by the United States Geological Survey and cooperative parties. The stations are arranged by stream basins and appear in systematic order for the several islands, tributaries of main streams being indicated by indention. The date refers to the years or parts of years for which records are available. A dash following the date indicates that the station was being maintained December 31, 1913.

KAUAI ISLAND.

Waimea River near Waimea, 1910–
- Poomau River:
  - Kawaikoi Stream near Waimea, 1909–
    - Waiakoali Stream near Waimea, 1909–1912.
  - Mohihi Stream near Waimea, 1909–1912.
- Waialae River near Waimea, 1910–
- Kekaha ditch at Weir, Camp No. 1, near Waimea, 1910–1912.
- Kekaha ditch at flume No. 3, near Waimea, 1910–1912.
- Kekaha ditch at siphon, near Waimea, 1910–1912.
- Kekaha ditch at tunnel No. 12 weir, near Waimea, 1910–1912.
- Waimea ditch near Waimea, 1911–1913.
- Kamenehune ditch near Waimea, 1911–12.
- Makaweli River near Waimea, 1911–
  - Halekua Stream near Waimea, 1912–13.
  - Olokele River:
    - Olokele ditch at tunnel No. 12, near Makaweli, 1904–
    - Olokele ditch near Makaweli, 1912–
  - Poowaiomahaihai ditch near Waimea, 1911–1913.

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Hanapepe River above Hanapepe Falls, near Eleele, 1911–12.
Hanapepe River at Koula, near Eleele, 1910–
Hiloa ditch at Hanapepe Falls, near Eleele, 1911–
East Branch Hanapape River below Hanapepe Falls, near Eleele, 1911–12.
Hanapepe ditch below Hanapepe Falls, near Eleele, 1911–12.
Hanapepe ditch at Koula, near Eleele, 1910–
Hanapepe ditch at weir, near Hanapepe, 1910–
Huleia River near Lihue, 1912–
Hanamaulu River at Kapaia, near Lihue, 1911–
Wailua River:
South Fork of Wailua River at siphon, near Lihue, 1910–11.
South Fork of Wailua River above Waiehu Falls, near Lihue, 1911–
Hanamaulu ditch near Lihue, 1910–
Lihue ditch near Lihue, 1910–
North Fork of Wailua River near Lihue, 1910–
Kanaha ditch near Lihue, 1910–
East Branch of North Fork of Wailua River, near Lihue, 1912–
Uhau Iole Stream at 750-foot elevation, near Lihue, 1912.
Keahua Stream at 750-foot elevation, near Lihue, 1912.
Kawi Stream at 750-foot elevation, near Lihue, 1912.
Konohiki Stream at Makakualele weir (mauka), near Kapaa, 1911–
Kaehulua Stream at Kuhinoa (mule stable) weir, near Kapaa, 1911–1913.
South Fork of Kaehulua Stream at Wainamuamu weir, near Kapaa, 1911–12.
North Fork of Kaehulua Stream at Wainamuamu weir, near Kapaa, 1911–
Kapaa River, near Kealia, 1910–
Akulikuli Spring near Kealia, 1911–1913.
Kapahi ditch at Kapahi, near Kealia, 1909–
Tunnel ditch at Kapahi, near Kapaa, 1909–1911.
Kapaa ditch at Kapahi, near Kapaa, 1909–1911.
Pipe ditch at Kapahi, near Kapaa, 1909–1911.
Kealia Stream:
Kaneha ditch near Kealia, 1909–
Anahola River at 1,140-foot elevation, near Kealia. 1912.
Anahola River above dam at Kiokala, near Kealia, 1910. 1912–
Anahola River at Kiokala dam, near Kealia, 1910–1912.
Anahola ditch at Kiokala, near Kealia, 1909–
Anahola ditch at Makai weir, near Kealia, 1909–1911.
Kalihiwai River near Kilauea, 1912–
Hanalei River near Hanalei, 1911–
China ditch near Hanalei, 1911–12.
Kuna ditch near Hanalei, 1912–13.
Lumahai River near Wainiha, 1912.
Wainiha River, East Channel, near Wainiha, 1912–
Wainiha River, West Channel, near Wainiha, 1911–
Wainiha canal at intake, near Wainiha, 1910–1912.
Wainiha canal at tunnel No. 18, near Wainiha, 1911.
Wainiha canal at tailrace, near Wainiha, 1911.

OAHU ISLAND.

Kalihi Stream at Kioi pool near Honolulu, 1913–
Nuuanu Stream at Luakaha weir in upper Nuuanu Valley, near Honolulu, 1903, 1910–13.
Nuuanu Stream below Reservoir No. 2 wasteway, near Honolulu, 1913–

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Nuuanu Stream at Kuakini Street, near Honolulu, 1911–12.
    Lulumaha ditch at upper Nuuanu Reservoir, near Honolulu, 1911–1913.
Pauoa Stream at upper Pauoa Valley, near Honolulu, 1911–
    Kahuawai Spring at upper Pauoa Valley, near Honolulu, 1912–
Manoa Stream at upper Manoa Valley, near Honolulu, 1910–1913.
Manoa Stream at College of Hawaii, near Honolulu, 1909–
    West Branch of Manoa Stream at upper Manoa Valley, near Honolulu, 1913–
    East Branch of Manoa Stream at upper Manoa Valley, near Honolulu, 1913–
Palolo Stream.
    Pukele Stream at Mahoe springs, near Honolulu, 1912–
    Waiomao Stream at upper Palolo Valley, near Honolulu, 1911–13.
    Waiomao Stream above Pukele, near Honolulu, 1911–12.
Waimanalo ditch below main reservoir, near Waimanalo, 1912–13.
Pump ditch near Waimanalo, 1912.
Makawao ditch at Makawao flume, near Waimanalo, 1912–
Kailua Stream near Kailua, 1912–
    Makawao Stream in Kailua Valley, near Kailua, 1912–
    Kaimi Stream in Kailua Valley, near Kailua, 1912–
    Kamakalepo Stream in Kailua Valley, near Kailua, 1912–
    Pohakea Stream in Kailua Valley, near Kailua, 1912–
Kahanaiki Stream in Kailua Valley, near Kailua, 1912.
    South Branch Kahanaiki Stream in Kailua Valley, near Kailua, 1913–
    North Branch Kahanaiki Stream in Kailua Valley, near Kailua, 1913–
    Kahanaiki ditch in Kailua Valley, near Kailua, 1912–13.
Waiahole Stream at Manianiaula, near Waikane, 1911–
Waiahole Stream at Waiahole, near Waikane, 1911–12.
    Waihi Stream, near Waikane, 1911.
    Halona Stream, near Waikane, 1911.
    Waianu Stream, near Waikane, 1911.
Waikane Stream near Waikane, 1911–12.
Punaluu Stream near Hauula, 1906–7.
Kaluanui Stream near Hauula, 1906–7.
Kaipapau Stream near Hauula, 1906–7.
Kaukonahua Stream:
    North Fork of Kaukonahua Stream near Wahiawa, 1911.
        Right Branch of North Fork of Kaukonahua Stream near Wahiawa, 1913–
        Left Branch of North Fork of Kaukonahua Stream near Wahiawa, 1913–
    South Fork of Kaukonahua Stream near Wahiawa, 1911, 1913–
    Wahiawa Reservoir ditch near Wahaiwa, 1910–11.

MAUI ISLAND.

West Maui.

Iao Stream near Wailuku, 1910–
    Maniania ditch near Wailuku, 1909–1913.
Waiehu Stream:
    South Waiehu Stream near Wailuku, 1910–
        South Waiehu ditch near Wailuku, 1912–
    North Waiehu Stream near Wailuku, 1912–
        North Waiehu ditch near Wailuku, 1910–11.
Waihee Stream near Waihee, 1910–1912, 1913—
    Waihee canal near Waihee, 1910–1912.
    Waihee canal at weir, near Wailuku, 1911–12.
    Spreckels ditch near Waihee, 1910–1913.
    Spreckels ditch at Waiale weir, near Wailuku, 1910–11.

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Kahakuloa Stream at Kahakuloa, near Waihee, 1912–13.
Kahakuloa Stream near Honokahau, 1913–
Honokahau Stream near Honokahau, 1913–
Honokahau ditch at intake, near Honokahau, 1907–1913.
Honokahau ditch above Honolua Stream, near Honokahau, 1910–11.
Honokahau ditch at Honokawai weir, near Lahaina, 1910–1912.
Honolua Stream at Honolua ranch, 1911.
Honolua Stream near Honokahau, 1913–
Honolua ditch near Honokahau, 1911–12.
Honokawai Stream near Lahaina, 1911; 1912–
Honokawai Stream at weir No. 1, near Lahaina, 1901.
Honokawai ditch near Lahaina, 1912–
Kahoma Stream near Lahaina, 1911–12.
Kahoma Stream at weir No. 1, near Lahaina, 1901.
Kahoma Stream at weir No. 2, near Lahaina, 1901.
Kahoma ditch at weir, near Lahaina, 1911–
Lahainaluna Stream near Lahaina, 1911–
Lahainaluna weir No. 1 near Lahaina, 1901.
Lahainaluna weir No. 2 near Lahaina, 1901.
Lahainaluna ditch near Lahaina, 1913–
Kauaula Stream near Lahaina, 1912.
Kauaula Stream at weir No. 3, near Lahaina, 1901.
Kauaula ditch near Lahaina, 1911–
Kauaula Stream, North Fork, at weir No. 1, near Lahaina, 1901.
Kauaula Stream, South Fork, at weir No. 2, near Lahaina, 1901.
Launiupoko Stream near Lahaina, 1911–
Olowalu Stream near Olowalu, 1913.
Olowalu ditch No. 1 near Olowalu, 1911–
Ukumehame Stream near Olowalu, 1911–12.
Waikapu Stream near Waikapu, 1910–
Palolo (Everett) ditch near Waikapu, 1910–
South Side Waikapu ditch near Waikapu, 1910–

East Maui.

Koolau Ditch region:
Koolau ditch near Keanae, 1910–1912.
Koolau ditch at Alo division weir, near Huelo, 1908–1911.
Spreckels ditch region:
Haipuaena Stream near Huelo, 1910–.
Puohakamoa Stream near Huelo, 1910–.
Alo Stream near Huelo, 1910–.
Waikamoi Stream near Huelo, 1910–.
Oopuola Stream near Huelo, 1910–.
Spreckels ditch at station No. 1, near Huelo, 1910–1913.
Spreckels ditch at station No. 2, near Huelo, 1911–1913.
Spreckels ditch at station No. 3, near Huelo, 1910–1913.
Spreckels ditch at station No. 4, near Huelo, 1910–1913.
Spreckels ditch at station No. 5, near Huelo, 1911–1913.
Spreckels ditch at station No. 6, near Huelo, 1911–1913.
Spreckels ditch at station No. 7, near Huelo, 1911–12.
Spreckels ditch at station No. 8, near Huelo, 1911–1913.
Center ditch region:
Center ditch near Huelo, 1910–1912.

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Hamakua ditch region:
- Nailiilihaele Stream near Huelo, 1910–1912; 1913–
- Kailua Stream near Huelo, 1910–1912; 1913–
- Oanui Stream near Huelo, 1910–11; 1913–
- Hoolawaliilii Stream near Huelo, 1911–
- Hoolawanui Stream near Huelo, 1911–
- Honopou Stream near Huelo, 1910–
- Halehaku Stream at dam, near Huelo, 1910–11.
- Halehaku Stream weir near Huelo, 1910–1912.
- Opana Stream near Huelo, 1910–1912.
- Opana ditch near Huelo, 1910–1912.
- New Hamakua ditch at Nailiilihaele weir, near Huelo, 1910–1912.
- New Hamakua ditch at Halehaku weir, near Huelo, 1910–1912.
- New Hamakua ditch at station No. 1, near Huelo, 1912.
- New Hamakua ditch at station No. 2, near Huelo, 1912.
- New Hamakua ditch at station No. 3, near Huelo, 1912.
- New Hamakua ditch at station No. 4, near Huelo, 1912.
- New Hamakua ditch at station No. 5, near Huelo, 1912.
- Old Hamakua ditch at Opana weir, near Huelo, 1910–1912.
- Kaluanui ditch at Puuomalei, near Hamakuapoko, 1910–1912.
- Lowrie ditch at Opana weir, near Huelo, 1910–1912.
- Haiku ditch at Peahi weir, near Huelo, 1910–1912.

HAWAII ISLAND.

Hilo group:
- 81 stations at 2,700 feet elevation, in forest back of Hilo, 1911–1913.
- Wailuku River near Hilo, 1911–1913.
- Honolii River at Kaiwiki, near Hilo, 1911–1913.
- Honolii ditch at Kaiwiki, near Hilo, 1911.
- Kawainui River at Kawainui, near Pepeekeo, 1911–12.
- 4 stations at Piihonua, near Hilo, 1912.

Hamakua group:
- Waipio River below Koiawe, near Waipio, 1911–12.
- Waipio River below Waima, near Waipio, 1911–12.
- Waipio River at 360 feet elevation, near Waipio, 1901–2.
  - New Hamakua ditch at Waima Stream, near Waipio, 1912.
  - New Hamakua ditch at main weir, near Kukiuhaele, 1910–
  - Hamakua ditch at main weir, at Puualala, Waimea, 1913.
  - Kawainui Branch of Waipio River, near Waipio, 1911–12.
  - Kawainui Stream at 2,120 feet elevation, near Waipio, 1901–2.
  - Kawainui Stream at 1,435 feet elevation, near Waipio, 1901–2.
  - Kawainui Stream at 775 feet elevation, near Waipio, 1901–2.
    - Branch No. 3 of Kawainui Stream at 1,700 feet elevation, near Waipio, 1901–2.
    - Branch No. 2 of Kawainui Stream at 1,405 feet elevation, near Waipio, 1901–2.
    - Branch No. 1 of Kawainui Stream at 1,380 feet elevation, near Waipio, 1901–2.
  - Alakahi Stream at 1,200 feet elevation, near Waipio, 1901–2.
  - Alakahi Stream at 730 feet elevation, near Waipio, 1901–2.
  - Koiawe Stream at 1,120 feet elevation, near Waipio, 1901–2.
  - Koiawe Stream at 610 feet elevation, near Waipio, 1901–2.
  - Waima Stream at 790 feet elevation, near Waipio, 1901–2.
  - Waima Stream at 385 feet elevation, near Waipio, 1901–2.

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Kohala group:

Honokane Stream:

East Branch of Honokane Stream at 1,300 feet elevation, near Honokane, 1901.
East Branch of Honokane Stream at 770 feet elevation, near Honokane, 1901.
West Branch of Honokane Stream at 1,370 feet elevation, near Honokane, 1901.
West Branch of Honokane Stream at 775 feet elevation, near Honokane, 1901.
Kohala ditch near Kohala, 1901–1913.
Kehana ditch at Honokane Mauka, near North Kohala, 1912–13.

GAGING-STATION RECORDS.

ISLAND OF KAUAI.

WAIMEA RIVER NEAR WAIMEA, KAUAI.

Location.—About 2 miles north of Waimea, 250 feet above ford.
Records available.—July 9, 1910, to December 31, 1913.
Drainage area.—58 square miles.
Gage.—Vertical and inclined staff.
Control.—Shifting.
Discharge measurements.—Made from wire suspension bridge or by wading.
Diversion.—Greater part of low-water flow diverted by irrigation ditches above station.
Accuracy.—Records good except for November and December, when fair results were obtained.

Daily discharge, in second-feet, of Waimea River near Waimea, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.2	6.6	3.2	0.2	12	1.0	34	1.6	373	0.6	283	0.6
2	192	2.2	2.2	42	2.2	1.0	397	1.4	38	.6	246	.4
3	47	2.2	3.2	14	2.2	186	184	1.1	24	.6	182	.4
4	7.3	2.2	2.2	2.2	1.6	12	572	1.0	20	65	6.6	.2
5	2.4	2.2	1.6	1.0	1.0	4.1	545	1.7	76	60	4.1	.2
6	2.2	2.2	.6	1.0	1.0	4.1	165	1.6	3.3	57	2.8	.2
7	2.2	2.2	.2	1.0	.2	2.2	151	1.7	1.5	1.8	2.2	.2
8	2.1	212	.2	.2	.2	2.2	20	1.4	1.2	3,340	2.1	.1
9	24	5.4	3.2	4.1	.2	1.0	2.2	1.4	1.0	320	2.1	.1
10	6.1	2.2	2.2	8.3	.1	1,490	2.1	1.6	.9	277	1.8	.1
11	186	255	1.0	815	.1	357	1.8	1.6	.8	264	6.6	80
12	6.6	432	1.0	540	3,340	102	1.5	1.5	.8	78	10,000	397
13	489	2.2	.2	320	2,190	47	47	6.6	.8	74	10,000	255
14	4.8	2.2	.2	226	780	10	1,150	2.2	1.0	69	9,300	240
15	6.6	2.2	.2	320	226	4.1	182	17	.9	65	9,000	226
16	30	2.2	.2	5.4	47	2.2	67	3.0	.9	53	8,900	221
17	4.4	2.2	1.0	.1	5.4	2.2	.....	19	1.0	47	397	8.0
18	3.2	2.2	1.0	1.0	24	2.2	2.6	14	1.0	42	320	8.0
19	2.6	24	.6	1.0	2.2	3.3	2.2	2.1	3.5	41	306	8.3
20	441	2.2	.2	.2	2.2	2.1	81	1.5	3.2	38	300	6.4
21	6.9	6.6	1.6	255	1.0	1.7	4.1	1.6	1.2	36	296	6.4
22	5.8	4.1	1.0	212	1.0	1.1	3.3	1.6	2.8	540	286	6.4
23	2.2	2.2	.2	199	.2	1.0	2.1	1.4	2.2	1,310	58	5.8
24	2.1	357	1,940	94	.1	3.2	1.2	1.6	1.8	320	52	5.6
25	.4	111	996	47	4.1	1.7	1.1	3.2	1.7	277	49	5.4
26	2.2	30	270	27	4.1	115	2.1	1.8	1.7	258	47	5.1
27	2.2	6.6	47	12	2.2	34	2.2	1.6	640	76	42	4.6
28	2.2	2.2	22	1.0	1.0	21	2.0	1.5	165	72	38	3.5
29	2.2	.....	6.6	.2	1.0	3.9	1.7	189	158	68	.8	2.8
30	2.1	.....	1.0	.2	1.0	2.4	1.8	62	29	3.5	.8	2.2
31	140	.....	1.0	.....	1.0	.....	1.7	174	.....	3.3	.....	1.6

NOTE.—No discharge July 17.

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Monthly discharge of Waimea River near Waimea, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	489	0.4	52.6	3,230	A.
February	432	2.2	53.1	2,950	A.
March	1,940	.2	50.5	3,110	A
April	815	.1	105	6,250	A.
May	3,340	.1	215	13,200	A.
June	1,490	1.0	80.7	4,800	A.
July	1,150	(a)	117	7,190	A.
August	189	1.0	16.8	1,030	A.
September	640	.8	51.9	3,090	A.
October	3,340	.6	254	15,600	A.
November	10,000	.8	1,670	99,400	B.
December	397	.1	48.4	2,980	B.
The year	10,000	(a)	225	163,000	

a Channel dry.

KAWAIKOI STREAM NEAR WAIMEA, KAUAI.

Location.—8 miles northeast of Knudsen's mountain house, and about 27 miles north of Waimea by horse trail.

Records available.—April 3, 1909, to December 31, 1913.

Drainage area.—4.1 square miles.

Gage.—Barrett & Lawrence water-stage recorder.

Control.—Probably permanent.

Discharge measurements.—Made from a wire suspension bridge or by wading.

Accuracy.—Records good.

Discharge measurements of Kawaikoi Stream near Waimea, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec. ft.*			*Feet.*	*Sec. ft.*
Apr. 8	D. E. Horner	1.86	12.6	June 5	D. E. Horner	2.28	44.4
May 5	W. V. Hardy	1.80	8.44	July 7	W. V. Hardy	2.68	50.3
June 4	D. E. Horner	3.49	123				

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Daily discharge, in second-feet, of Kawaikoi Stream near Waimea, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	.....	.....	13	14	9	34	8	4.5	26
2	.....	.....	.....	.....	.....	23	14	8	25	7	69	20
3	.....	.....	10	.....	.....	20	13	8	16	4.5	55	31
4	18	.....	9	.....	.....	68	20	7	8	4	16	80
5	14	.....	.....	.....	9	23	24	7	8	4	12	110
6	14	.....	.....	.....	16	16	23	7	8	4	9	127
7	15	15	.....	.....	23	16	47	11	8	74	82	53
8	.....	32	.....	.....	15	14	22	20	8	82	27	50
9	.....	.....	.....	.....	12	13	17	20	7	18	24	31
10	.....	.....	.....	.....	10	13	14	12	7	13	17	21
11	.....	.....	.....	.....	63	13	13	9	7	12	80	18
12	.....	.....	.....	.....	68	13	30	18	9	10	119	17
13	.....	.....	.....	.....	53	13	114	22	9	7	68	16
14	.....	.....	.....	.....	16	13	63	39	14	7	21	15
15	.....	.....	.....	.....	14	14	22	30	10	7	15	15
16	.....	.....	.....	.....	16	15	17	98	8	6	66	15
17	.....	.....	.....	.....	55	14	15	26	7	5	109	14
18	.....	.....	.....	.....	36	14	13	18	30	5	82	14
19	.....	.....	.....	.....	15	12	18	11	17	5	190	13
20	.....	.....	.....	.....	13	11	33	9	10	5	75	12
21	.....	.....	.....	.....	11	12	20	8	11	5	31	11
22	.....	.....	.....	.....	10	12	15	7	14	5	92	11
23	.....	.....	.....	.....	8	12	13	7	8	6.5	152	11
24	.....	.....	.....	.....	8	12	14	28	4.5	12	172	10
25	.....	.....	.....	.....	8	12	16	18	6	18	100	10
26	.....	.....	.....	.....	8	12	14	19	5	12	44	9
27	.....	.....	.....	.....	8	12	12	18	4.5	11	31	8
28	.....	.....	.....	.....	8	12	9	13	5	7	24	8
29	.....	.....	.....	.....	8	14	9	22	5	5	28	9
30	.....	.....	.....	.....	8	14	9	20	4	4.5	36	9
31	.....	.....	.....	.....	8	.....	9	36	.....	4.5	.....	11

NOTE.—No records Jan. 1-3, Jan. 8 to Feb. 6, Feb. 9 to Mar. 2, and Mar. 5 to May 4.

Monthly discharge of Kawaikoi Stream near Waimea, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May 4-31	.....	.....	19.5	1,040	A.
June	68	11	15.8	940	A.
July	114	9	22.1	1,360	A.
August	98	7	18.9	1,160	A.
September	34	4	10.6	631	A.
October	82	4	12.2	750	A.
November	190	4.5	61.7	3,670	A.
December	127	8	26.0	1,600	A.
The period	.....	.....	.....	11,200	

WAIALAE RIVER NEAR WAIMEA, KAUAI.

Location.—3 miles northeast of F. Gay's mountain house, and about 20 miles northeast of Waimea by horse trail.

Records available.—August 1, 1910, to December 31, 1913.

Drainage area.—3.5 square miles.

Gage.—Barrett & Lawrence water-stage recorder.

Control.—Probaby permanent.

Discharge measurements.—Made from cable or by wading.

Accuracy.—Records January to August, good; September to December, fair.

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Discharge measurements of Waialae River near Waimea, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	D. E. Horner	1.56	28.9	June 9	D. E. Horner	1.64	35.9
May 9	do	1.22	8.83				

Daily discharge, in second-feet, of Waialae River near Waimea, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.2	3.5	8.0	39	26	7.2	24	6.9	30	5.5	7.6	18
2	7.2	3.6	8.0	21	23	6.9	50	6.3	41	5.2	8.0	11
3	7.2	3.9	7.6	11	38	8.3	44	6.0	31	4.3	30	10
4	7.2	4.3	7.6	10	21	14	39	6.0	13	4.3	11	13
5	7.2	4.3	7.6	7.6	16	11	50	5.5	11	4.3	9.9	23
6	7.2	4.3	7.6	6.9	15	11	31	5.8	11	4.3	9.9	48
7	7.2	5.5	7.2	6.6	12	11	24	6.3	11	5.8	14	15
8	43	34	6.6	6.3	11	9.1	24	6.9	10	105	16	10
9	20	16	5.5	9.1	7.6	8.7	17	7.2	7.2	26	41	8.0
10	50	18	5.5	24	7.2	36	11	7.2	7.2	11	26	8.0
11	50	36	4.2	34	24	41	9.1	7.2	6.0	10	108	7.2
12	16	16	3.0	20	100	17	8.0	7.2	5.8	9.1	122	7.2
13	122	11	3.0	84	70	15	8.0	10	5.8	57	126	7.2
14	34	9.5	3.0	51	29	23	14	15	5.8	36	24	6.3
15	27	9.1	3.0	93	18	12	13	17	5.8	26	21	4.9
16	32	8.3	3.0	30	17	11	9.9	24	5.8	20	23	4.3
17	13	8.0	3.0	36	16	8.3	8.3	17	5.8	15	24	4.3
18	9.5	8.0	4.0	44	16	7.6	8.0	16	5.8	14	17	5.5
19	8.0	8.0	4.0	34	16	7.2	8.3	10	5.8	26	70	5.5
20	7.6	8.0	7.2	20	13	7.2	8.3	8.0	5.8	19	63	5.5
21	7.2	8.0	7.6	18	11	7.2	9.1	7.6	5.8	16	18	5.8
22	6.9	8.0	17	16	10	7.2	7.6	7.2	5.5	17	25	5.2
23	6.6	7.2	15	16	8.0	6.9	7.2	7.2	5.5	31	60	4.9
24	6.0	39	54	16	7.6	6.3	7.2	6.6	5.2	23	58	4.9
25	5.8	20	62	51	7.2	6.3	7.2	6.9	4.9	30	61	5.5
26	5.8	16	41	28	7.2	30	7.2	6.6	4.3	22	43	5.5
27	5.2	11	14	18	7.2	17	7.2	6.3	4.0	28	11	5.2
28	4.2	9.1	11	18	7.2	18	7.2	17	6.0	14	18	5.8
29	3.8	.....	7.2	45	7.2	14	7.2	68	5.5	13	50	6.3
30	3.5	.....	6.3	41	7.2	9.1	7.2	18	5.5	11	72	6.3
31	3.5	.....	6.3	.....	7.2	.....	6.9	32	.....	8.0	.....	6.6

Monthly discharge of Waialae River near Waimea, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	122	3.5	17.5	1,080	A.
February	39	3.5	12.1	672	A.
March	62	3.0	11.3	695	A.
April	93	6.3	28.5	1,700	A.
May	100	7.2	18.8	1,160	A.
June	41	6.3	13.2	786	A.
July	50	6.9	15.8	972	A.
August	68	5.5	12.2	750	A.
September	41	4.0	9.43	561	B.
October	105	4.3	20.0	1,230	B.
November	126	7.6	39.6	2,360	B.
December	48	4.3	9.16	563	B.
The year	126	3.0	17.3	12,500	

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WAIMEA DITCH NEAR WAIMEA, KAUAI.

Location.—About 4 miles north of Waimea and 300 feet below intake.
Records available.—November 4, 1911, to September 30, 1913.
Gage.—Vertical staff.
Control.—Fairly permanent.
Discharge measurements.—Made from a footbridge.
Diversion.—Ditch diverts part of flow of Waimea River.
Accuracy.—Records poor.

Monthly discharge of Waimea ditch near Waimea, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	12.1	1.9	4.97	306	C.
February	15.3	1.5	4.21	234	C.
March	10.6	1.0	3.84	236	C.
April	27.5	2.4	7.98	472	C.
May	13.7	3.2	5.61	345	C.
June	16.1	2.4	6.25	372	C.
July	16.1	1.5	7.16	440	C.
August	15.3	2.0	4.73	291	C.
September	12.1	1.7	4.02	239	C.
The period				2,940	

MAKAWELI RIVER NEAR WAIMEA, KAUAI.

Location.—About 2 miles northeast of Waimea. Reached by wagon road up Makaweli River.
Records available.—October 6, 1911, to December 31, 1913.
Drainage area.—25.8 square miles.
Gage.—Vertical staff.
Control.—Probably slightly shifting.
Discharge measurements.—Made from a wire suspension footbridge or by wading.
Diversions.—Several above station.
Accuracy.—Records fairly good except for November and December, when they were poor.

The following discharge measurement was made by W. V. Hardy:
April 30, 1913: Gage height, 4.46 feet; discharge, 195 second-feet.

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Daily discharge, in second-feet, of Makaweli River near Waimea, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	14	15	17	55	39	6	22	10	30	24	82	13
2	14	14	17	14	9	6	24	12	26	34	80	12
3	13	14	14	12	6	226	72	11	24	25	78	12
4	3	13	11	12	84	34	47	10	24	50	80	12
5	3	13	11	8	13	14	55	10	17	44	69	11
6	17	12	11	6	19	11	23	8	16	37	70	11
7	14	10	10	6	17	6	18	8	16	35	74	10
8	10	9	10	6	8	6	17	9	16	621	74	9
9	10	8	10	55	8	6	18	8	15	320	84	9
10	3	84	10	15	6	39	18	8	14	260	93	8
11	190	32	10	10	6	17	18	7	13	82	3,160	9
12	26	26	10	26	1,280	15	18	7	13	78	1,920	9
13	2,660	20	6	383	190	15	18	7	12	72	255	8
14	84	20	6	84	39	17	19	6	12	74	166	8
15	84	19	6	126	34	17	19	6	11	148	154	7
16	143	17	6	84	20	14	18	6	10	143	118	7
17	84	17	19	34	19	11	18	7	10	190	106	7
18	26	14	9	21	14	12	18	7	11	98	135	7
19	26	14	9	20	14	10	18	7	12	93	139	7
20	14	17	13	19	12	11	18	6	11	82	143	7
21	14	26	12	19	6	10	16	6	10	80	135	7
22	14	20	36	14	6	10	15	6	10	76	139	7
23	13	20	10	10	14	9	8	7	10	78	150	7
24	13	19	44	11	10	9	7	7	11	75	154	7
25	14	84	122	14	11	9	7	6	10	74	5,170	7
26	19	55	39	14	10	8	7	6	9	72	1,790	6
27	17	26	10	13	10	247	8	6	4	75	289	6
28	19	20	8	6	6	104	9	6	6	80	232	6
29	19	.....	6	122	6	16	7	6	6	80	202	2
30	17	.....	6	84	6	58	8	70	4	81	13	2
31	14	.....	6	.....	6	.....	8	74	.....	81	.....	2

Monthly discharge of Makaweli River near Waimea, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	2,660	3	116	7,130	B.
February	84	8	23.5	1,310	A.
March	122	6	16.6	1,020	B.
April	383	6	43.4	2,580	A.
May	1,280	6	62.2	3,820	B.
June	247	6	32.4	1,930	B.
July	72	7	19.2	1,180	A.
August	74	6	11.6	713	B.
September	30	4	13.1	780	B.
October	621	24	108	6,640	B.
November	5,170	13	512	30,500	C.
December	13	2	7.81	480	C.
The year	5,170	2	80.3	58,100	

HALEKUA STREAM NEAR WAIMEA, KAUAI.

Location.—Station is reached from Waimea via Gay's mountain house by saddle horse; requires two days to make round trip.

Records available.—October 11, 1912, to December 18, 1913.

Drainage area.—0.5 square mile.

Gage.—Barrett & Lawrence water-stage recorder.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Accuracy.—Records fair.

Cooperation.—Station maintained in cooperation with Hawaiian Sugar Co.

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Discharge measurements of Halekua Stream near Waimea, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 10	D. E. Horner	3.90	10.8	Oct. 12	W. V. Hardy	3.50	1.68
Sept. 11	do	3.36	.65				

Daily discharge, in second-feet, of Halekua Stream near Waimea, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1			2.2	7.8	3.8	2.2				1.0		
2			1.9	4.3	9.2	5.0						
3			1.9	4.5	4.2	4.7						19
4			1.9	3.3	3.5	3.0					1.5	1.4
5			1.9	3.0	3.3	2.9					1.5	3.0
6			2.0	2.7	3.3						2.3	2.7
7			2.0	2.6	3.3						3.3	1.4
8			1.8	3.3	3.0			2.5			5.0	1.2
9			1.6	5.5	2.6			2.7			5.0	.8
10			1.5	5.8	2.6			2.3			35	.8
11			1.4	4.0	20	8.9		2.0	0.8	2.9	53	.7
12		1.9	1.2	3.5	19	3.3		2.3	.8	2.0		.6
13		1.9	1.1	22	13	4.2		2.7	.8	9.2		.6
14		1.9	1.1	8.2	4.2	3.5		3.3		2.7		.6
15		1.8	1.2	11	5.8	3.3		3.0		1.5		.6
16		1.7	1.4	4.2	3.8	2.7		3.8		1.4		.6
17		1.7	1.7	6.0	3.6	2.5		1.9		1.4		.6
18		1.8	1.9	5.0	4.2	2.9		1.3		2.2		.6
19		1.8	2.5	5.8	2.9					1.7		
20		1.8	4.0	3.3	2.7		2.6			1.3		
21		1.9	3.3	3.3	2.6		2.6			1.0		
22		1.9	5.0	2.9	2.6		2.6			1.7		
23		4.2	7.5	3.3	2.5		2.3			1.9		
24		4.2	9.2	4.0	2.6		2.5			1.5		
25		3.0	12	8.6	2.6		2.5			3.0		
26		2.7	5.0	3.5	2.5		2.3					
27		2.6	4.3	3.3	2.5		2.2					
28		2.5	3.5	7.0	2.5		1.9		1.0			
29			3.2	7.5	2.5		2.0		.8			
30			2.9	6.0	2.5		2.0		.8			
31			9.2		2.5		1.9					

NOTE.—No record for days for which discharge measurements are not given.

OLOKELE DITCH AT TUNNEL NO. 12, NEAR MAKAWELI, KAUAI.

Location.[1]—About 10 miles northeast of Makaweli.
Records available.—July 24, 1904, to December 31, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from a plank across ditch.
Diversion.—Ditch diverts all low-water flow of Olokele River.
Accuracy.—Records excellent.
Cooperation.—Gage-height records furnished by Hawaiian Sugar Co.

Discharge measurements of Olokele ditch at tunnel 12, near Makaweli, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 27	W. V. Hardy	3.54	95.9	Apr. 27	W. V. Hardy	3.04	78.9
27	do	3.24	86.0	June 27	do	3.84	106

[1] Described in U. S. Geol. Survey Water-Supply Paper 336 as about "12 miles northeast of Waimea."

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Daily discharge, in second-feet, of Olokele ditch at tunnel 12, Makaweli, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	64	51	51	105	81	51	105	51	91	55	47	33
2	55	51	51	101	105	47	105	58	72	51	51	61
3	51	51	51	75	97	41	105	51	72	47	88	64
4	51	47	51	72	81	41	105	51	61	47	61	68
5	51	51	51	64	61	41	105	47	61	44	68	68
6	47	51	51	58	55	105	78	47	72	105	105	105
7	51	97	55	55	68	84	88	64	61	75	51	68
8	101	78	55	51	94	61	68	78	55	105	88	55
9	91	55	51	55	64	91	61	97	68	105	101	55
10	101	51	51	68	58	105	55	55	55	68	94	51
11	101	88	47	97	51	97	55	55	51	61	105	51
12	101	58	47	64	88	64	51	51	68	68	61	51
13	101	55	47	105	105	94	105	78	51	105	105	51
14	101	51	47	101	78	78	72	84	51	94	101	51
15	91	51	47	105	64	94	72	68	51	84	105	51
16	91	58	55	84	68	101	64	58	55	97	105	55
17	72	51	94	105	64	58	58	58	51	58	105	47
18	61	51	61	97	97	55	55	55	51	55	75	51
19	58	72	72	101	61	75	58	51	51	64	105	51
20	55	55	97	75	55	55	64	51	47	51	105	51
21	58	68	91	72	51	97	55	105	47	51	94	47
22	58	0	75	68	51	55	61	58	55	51	78	51
23	57	61	64	64	51	68	55	55	47	61	78	47
24	55	101	97	72	51	72	68	51	47	51	105	47
25	54	72	101	105	58	75	105	101	47	64	105	47
26	52	55	97	84	58	105	105	72	47	58	105	47
27	51	44	68	68	51	72	81	58	47	58	105	47
28	51	55	78	64	64	75	61	68	55	68	75	47
29	51	.....	61	105	51	75	105	105	51	51	68	47
30	51	.....	58	101	97	105	58	105	47	47	22	47
31	58	.....	61	.....	55	.....	55	105	.....	47	.....	47

Monthly discharge of Olokele ditch at tunnel 12, near Makaweli, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	101	47	67.5	4,150	A.
February	101	0	58.2	3,230	A.
March	101	47	64.0	3,940	A.
April	105	51	81.4	4,840	A.
May	105	51	68.8	4,230	A.
June	105	41	74.6	4,440	A.
July	105	51	75.4	4,640	A.
August	105	47	67.5	4,150	A.
September	91	47	56.2	3,340	A.
October	105	44	66.0	4,060	A.
November	105	22	85.4	5,080	A.
December	105	38	53.7	3,300	A.
The year	105	0	68.2	49,400	

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OLOKELE DITCH AT WEIR, NEAR MAKAWELI, KAUAI.[1]

Location.—About 7 miles northeast of Makaweli and about 3 miles below tunnel No. 12 on the same ditch.

Records available.—January 1, 1910, to December 31, 1913.

Gage.—Vertical staff; zero on gage is equal to crest of weir.

Discharge measurements.—Made from plank over ditch. Discharge computed by Francis formula for a 12-foot weir with end contractions; computations checked by current-meter measurements.

Diversion.—Ditch diverts all of low-water flow of Olokele River.

Accuracy.—Records good.

Cooperation.—Records are furnished by the Hawaiian Sugar Co.

Discharge measurements of Olokele ditch at weir, near Makaweli, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Feb. 14	W. V. Hardy	2.21	51.6
14	do	2.21	51.8

Daily discharge, in second-feet, of Olokele ditch at weir, near Makaweli, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	73.4	58.7	73.4	87.6	82.9	47.7	95.8	58.7	79.6	45.1	42.5	41.2
2	89.3	54.5	58.7	79.6	92.5	57.3	99.1	53.1	67.4	49.0	42.5	47.7
3	89.3	54.5	50.4	82.9	90.9	47.7	101	47.7	64.4	45.1	70.3	64.4
4	95.8	73.4	47.7	70.3	70.3	40.0	99.1	46.4	57.3	42.5	64.4	73.4
5	87.6	65.9	49.0	57.3	58.7	43.8	87.6	47.7	64.4	41.2	61.5	70.3
6	82.9	60.1	49.0	51.7	70.3	74.9	78.0	51.7	70.3	46.4	63.0	76.5
7	76.5	49.0	51.7	50.4	78.0	63.0	70.3	65.9	61.5	70.3	61.5	79.6
8	90.9	49.0	50.4	55.8	74.9	67.4	61.5	65.9	53.1	86.0	61.5	58.7
9	86.0	51.7	49.0	76.5	58.7	84.5	57.3	61.5	51.7	90.9	65.9	50.4
10	74.9	50.4	60.1	82.9	58.7	84.5	54.5	55.8	47.7	82.9	90.9	49.0
11	64.4	51.7	74.9	78.0	81.2	73.4	54.5	50.4	47.7	68.9	92.5	47.7
12	57.3	68.9	76.5	79.6	89.3	70.3	61.5	74.9	49.0	65.9	86.0	47.7
13	57.3	64.4	78.0	94.2	89.3	89.3	76.5	76.5	45.1	67.4	89.3	47.7
14	60.1	65.9	82.9	95.8	68.9	79.6	70.3	76.5	45.1	86.0	87.6	47.7
15	64.4	60.1	86.0	89.3	68.9	73.4	64.4	60.1	47.7	90.9	86.0	47.7
16	55.8	60.1	82.9	82.9	64.4	67.4	63.0	61.5	46.4	73.4	90.9	46.4
17	51.7	64.4	76.5	90.9	74.9	58.7	58.7	53.1	45.1	61.5	90.9	46.4
18	50.4	68.9	76.5	87.6	68.9	57.3	57.3	50.4	45.1	53.1	87.6	46.4
19	47.7	57.3	78.0	81.2	57.3	60.1	64.4	50.4	43.8	58.7	92.5	47.7
20	47.7	51.7	82.9	65.9	51.7	63.0	58.7	54.5	43.8	53.1	99.1	47.7
21	49.0	50.4	84.5	65.9	49.0	60.1	54.5	61.5	49.0	47.7	92.5	47.7
22	47.7	49.0	82.9	63.0	47.7	57.3	54.5	54.5	46.4	50.4	86.0	49.0
23	49.0	47.7	82.9	71.9	51.7	61.5	57.3	55.8	42.5	55.8	92.5	46.4
24	51.7	47.7	90.9	74.9	67.4	60.1	67.4	68.9	42.5	53.1	97.5	45.1
25	50.4	47.7	94.2	89.3	55.8	86.0	74.9	68.9	41.2	55.8	99.1	45.1
26	49.0	47.7	84.5	71.9	53.1	84.5	79.6	64.4	41.2	54.5	101	45.1
27	50.4	50.4	79.6	71.9	57.3	87.6	67.4	71.9	40.0	50.4	92.5	45.1
28	57.3	74.9	67.4	86.0	54.5	82.9	61.5	87.6	42.5	50.4	78.0	45.1
29	57.3	.....	64.4	92.5	57.3	73.4	67.4	87.6	58.7	50.4	70.3	43.8
30	61.5	.....	67.4	90.9	58.7	90.9	55.8	82.9	47.7	45.1	53.1	43.8
31	57.3	.....	84.5	.....	50.4	.....	51.7	84.5	.....	43.8	.....	43.8

[1] Described in U. S. Geol. Survey Water-Supply Paper 336 as about 8 miles northeast of Waimea.

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Monthly discharge of Olokele ditch at weir, near Makaweli, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	95.8	47.7	64.0	3,940	B.
February	74.9	47.7	57.0	3,170	B.
March	94.2	47.7	71.5	4,400	B.
April	95.8	50.4	77.3	4,600	B.
May	92.5	47.7	66.2	4,070	B.
June	90.9	40.0	68.2	4,060	B.
July	101	51.7	68.6	4,220	B.
August	87.6	46.4	62.9	3,870	B.
September	79.6	40.0	50.9	3,030	B.
October	90.9	41.2	59.2	3,640	B.
November	101	42.5	79.6	4,740	B.
December	79.6	41.2	51.1	3,140	B.
The year	101	40.0	64.8	46,900	

POOWAIOMAHAIHAI DITCH NEAR WAIMEA, KAUAI.

Location.—About 110 feet below bridge station on Makaweli River, 250 feet below intake, and about 2 miles northeast of Waimea.

Records available.—October 27, 1911, to September 30, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made from timber bridge 15 feet above gage.

Diversion.—Ditch diverts part of flow of Makaweli River.

Accuracy.—Records good.

The following discharge measurement was made by W. V. Hardy:
April 30, 1913: Gage height, 1.67 feet; discharge, 13.5 second-feet.

Daily discharge, in second-feet, of Poowaiomahaihai ditch near Waimea, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	4.3	6.2	7.3	8.5	7.3	3.5	6.5	5.7	8.4
2	4.3	6.2	7.3	5.2	4.3	2.8	6.8	6.1	7.9
3	4.3	6.2	7.3	3.5	4.3	8.5	7.2	6.0	7.5
4	3.5	5.2	6.2	3.5	8.5	7.3	6.8	5.8	6.8
5	3.5	5.2	6.2	2.8	4.3	5.2	6.2	5.7	6.2
6	4.3	5.2	6.2	2.8	6.2	4.3	6.1	5.5	6.0
7	4.3	5.2	5.2	2.8	6.2	3.5	5.9	5.5	6.0
8	5.2	5.2	5.2	2.8	4.3	3.5	5.7	5.4	6.1
9	5.2	4.3	5.2	8.5	4.3	3.5	5.9	5.2	5.9
10	3.5	13	5.2	4.3	3.5	7.3	5.8	5.2	5.7
11	3.5	7.3	5.2	3.5	3.5	5.2	5.8	5.1	5.5
12	7.3	7.3	5.2	7.3	25	5.2	5.7	4.9	5.5
13	39	6.2	4.3	18	8.5	4.3	5.8	4.9	5.3
14	14	7.3	4.3	8.5	7.3	3.5	5.9	4.8	5.3
15	18	7.3	4.3	9.8	7.3	3.5	5.9	4.6	5.2
16	18	7.3	4.3	8.5	6.2	3.5	5.8	4.6	5.1
17	13	7.3	7.3	7.3	6.2	5.4	5.8	4.6	4.9
18	6.2	7.3	4.3	6.2	5.2	5.2	5.8	4.6	5.2
19	6.2	6.2	4.3	7.3	5.2	5.2	5.7	4.6	5.3
20	4.3	7.3	5.2	6.2	5.2	5.3	5.7	4.5	5.2
21	4.3	8.5	5.2	6.2	3.5	5.3	5.5	4.5	5.1
22	4.3	7.3	7.3	6.2	3.5	5.4	5.3	4.6	5.1
23	5.2	7.3	4.8	5.2	5.2	5.2	5.0	4.8	5.0
24	5.2	7.3	6.2	5.2	4.3	5.1	4.8	4.8	5.2
25	4.3	9.8	9.8	6.2	4.3	5.1	4.8	4.6	4.9
26	5.2	8.5	6.2	5.2	4.3	4.9	5.0	4.6	5.9
27	4.3	7.3	4.8	5.2	3.5	12	5.1	4.6	5.7
28	5.2	7.3	4.3	4.3	3.5	10	5.0	4.5	6.2
29	4.3	.....	3.5	8.5	3.5	6.5	5.2	4.5	6.1
30	4.3	.....	3.5	7.3	3.5	10	5.3	7.0	5.6
31	4.3	.....	3.5	.....	3.5	.....	5.2	7.2	.....

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Monthly discharge of Poowaimahaihai ditch near Waimea, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	39	3.5	7.20	443	A.
February	13	4.3	6.99	388	A.
March	9.8	3.5	5.45	335	A.
April	18	2.8	6.23	371	A.
May	25	3.5	5.66	348	A.
June	12	2.8	5.53	329	A.
July	7.2	4.8	5.71	351	A.
August	7.2	4.5	5.13	315	A.
September	8.4	4.9	5.79	345	A.
The period				3,220	

HANAPEPE RIVER AT KOULA, NEAR ELEELE, KAUAI.

Location.—About 5 miles north of Eleele.
Records available.—August 18, 1910, to December 31, 1913.
Drainage area.—12.6 square miles.
Gage.—Friez water-stage recorder.
Control.—Fairly permanent.
Discharge measurements.—Made from cable or by wading.
Diversions.—Nearly all low-water flow diverted above station.
Accuracy.—Records fair.

The following discharge measurement was made by D. E. Horner:
October 14, 1913: Gage height, 1.56 feet; discharge, 46.3 second-feet

Daily discharge, in second-feet, of Hanapepe River at Koula, near Eleele, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	24	16	13	78	55	14	87	67	51	15	14	126
2	20	16	13	40	174	25	277	30	72	13	29	98
3	19	16	13	39	95	357	105	14	40	12	18	86
4	18	15	13	29	58	108	118	13	16	12	13	66
5	18	17	13	18	27	84	138	12	15	12	14	29
6	19	50	13	14	40	38	50	13	43	53	20	53
7	20	55	21	14	54	36	36	18	20	66	14	60
8	165	36	16	16	80	20	23	17	14	420	13	25
9	50	17	13	55	32	46	22	14	14	196	94	23
10	180	32	13	20	25	38	20	13	13	56	171	20
11	142	33	13	20	142	64	18	12	13	76	442	15
12	142	16	13	15	246	24	17	26	13	53	603	14
13	459	14	13	243	266	48	60	25	13	121	453	14
14	129	14	13	149	117	40	23	23	13	63	126	14
15	264	14	13	142	67	34	22	15	14	43	88	13
16	120	18	14	41	36	44	22	13	13	34	92	12
17	59	15	23	112	38	19	18	13	12	22	61	12
18	63	25	16	72	56	23	18	12	12	29	52	13
19	75	30	20	87	22	25	20	12	13	15	298	12
20	24	29	22	30	18	18	36	12	12	14	343	12
21	29	19	22	24	17	26	18	32	12	18	125	12
22	72	16	36	20	17	18	16	13	12	43	130	12
23	43	16	35	38	16	20	15	12	12	30	167	11
24	80	48	28	18	26	16	17	13	12	60	184	11
25	34	18	76	221	16	20	41	24	12	88	352	11
26	20	14	67	57	13	57	68	18	12	72	246	11
27	19	13	30	33	14	120	25	15	12	52	132	11
28	17	13	24	29	14	92	15	43	26	34	86	11
29	16	.....	29	82	14	36	29	143	12	15	363	11
30	16	.....	18	142	101	78	14	38	12	15	225	11
31	20	.....	22	.....	24	.....	14	123	.....	15	.....	11

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Monthly discharge of Hanapepe River at Koula, near Eleele, Kauai.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	459	16	76.6	4,710	B.
February	55	13	22.7	1,260	B.
March	76	13	22.2	1,360	B.
April	243	14	63.3	3,770	B.
May	266	13	61.9	3,810	B.
June	357	14	52.9	3,150	B.
July	277	14	45.2	2,780	B.
August	143	12	27.4	1,680	B.
September	72	12	18.7	1,110	B.
October	420	12	57.0	3,500	B.
November	603	13	166	9,880	B.
December	126	11	27.1	1,670	B.
The year	603	11	53.4	38,700	

HILOA DITCH AT HANAPEPE FALLS NEAR ELEELE, KAUAI.

Location.—About 8 miles north of Eleele and 335 feet below intake, which is just above confluence of the main and east branches of Hanapepe River.

Records available.—November 22, 1911, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made from plank across ditch at gage.

Diversion.—Ditch diverts all low-water flow from the main branch of Hanapepe River above Hanapepe Falls.

Accuracy.—Records good.

Discharge measurements of Hiloa ditch at Hanapepe Falls, near Eleele, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
June 21	W. V. Hardy	2.09	41.1
Oct. 14	D. E. Horner	2.18	45.5

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Daily discharge, in second-feet, of Hiloa ditch at Hanapepe Falls, near Eleele, Kauai, for 1912–13.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.												
1	34	31	37	29	29	36	37	32	40	44	40	54
2	35	31	31	29	30	34	32	31	41	30	35	62
3	35	30	32	28	43	33	30	30	40	39	34	42
4	34	30	33	37	53	39	38	32	37	30	32	42
5	50	29	30	31	44	37	46	35	38	31	54	42
6	38	29	36	30	34	35	31	34	35	32	43	41
7	41	29	32	37	34	32	31	45	40	34	35	40
8	44	29	31	44	45	33	31	45	40	41	46	42
9	44	29	50	43	35	32	31	52	40	33	46	43
10	40	32	54	40	31	31	43	36	36	35	40	40
11	35	30	58	39	31	32	53	34	34	30	35	37
12	35	29	42	36	32	31	42	32	35	31	33	36
13	39	28	45	33	32	54	48	32	34	32	31	36
14	29	28	43	32	44	44	46	55	32	33	30	33
15	35	28	40	32	45	46	43	38	37	31	30	34
16	33	28	40	32	38	39	44	37	42	30	29	34
17	32	29	40	40	32	32	52	33	36	47	39	32
18	32	28	40	39	31	41	41	32	31	35	49	31
19	31	28	35	32	30	44	40	31	35	52	33	33
20	43	28	35	47	30	37	40	31	33	50	31	44
21	37	29	34	46	34	50	40	31	32	48	34	61
22	31	40	35	44	44	43	39	40	32	44	46	62
23	56	50	31	44	46	46	39	31	31	42	54	63
24	18	39	36	32	49	49	51	39	30	35	42	50
25	26	36	42	55	39	40	39	38	29	34	31	46
26	26	34	33	38	44	34	38	38	29	52	29	42
27	26	32	31	35	48	36	36	38	28	49	29	39
28	28	31	30	33	39	32	34	41	30	46	28	40
29	31	30	30	31	34	31	33	40	36	43	32	39
30	30	.....	29	30	42	30	36	42	42	45	45	38
31	33	.....	33	.....	40	.....	32	40	.....	44	.....	41
1913.												
1	39	32	29	47	48	36	43	30	40	29	32	19
2	37	32	28	46	43	32	44	38	40	28	34	19
3	34	31	28	48	44	48	44	35	42	27	37	18
4	33	32	28	42	44	14	45	32	39	27	31	18
5	33	34	28	37	43	14	46	31	42	38	31	38
6	33	39	28	34	41	44	44	34	43	48	42	38
7	33	46	46	31	48	42	41	37	38	41	35	0
8	56	45	29	33	50	44	39	36	34	45	30	35
9	39	44	28	52	46	46	41	38	35	44	38	35
10	48	43	28	37	40	44	38	34	31	42	45	35
11	52	41	28	36	44	45	34	30	30	42	45	35
12	46	35	27	33	47	40	34	45	35	43	39	34
13	40	32	27	38	52	46	35	40	30	44	39	34
14	41	31	28	44	18	46	36	38	31	39	37	33
15	49	31	27	45	39	46	37	35	32	42	40	32
16	37	30	40	39	39	45	43	31	29	45	38	31
17	37	30	52	45	41	38	34	30	29	38	37	32
18	22	39	31	42	40	40	32	30	29	37	37	33
19	0	47	34	42	40	41	33	28	29	35	39	32
20	42	37	41	45	37	34	34	29	28	33	39	31
21	42	37	40	48	35	46	34	44	28	32	37	31
22	50	33	51	37	34	42	32	34	29	31	40	31
23	43	38	44	48	32	38	31	30	28	38	40	30
24	44	43	38	37	48	33	35	37	27	38	41	30
25	45	33	53	35	40	46	42	44	27	0	44	28
26	40	31	52	40	32	46	46	39	27	0	35	30
27	36	30	40	44	37	53	40	32	27	33	33	29
28	35	29	40	48	37	42	34	36	28	40	31	29
29	34	.....	52	48	34	41	44	48	28	33	31	29
30	33	.....	48	45	44	40	33	42	28	31	25	29
31	34	.....	43	.....	39	.....	32	41	.....	31	.....	30

NOTE.—Gage not read on Sundays; discharge estimated.

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Monthly discharge of Hiloa ditch at Hanapepe Falls, near Eleele, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
January	56	18	34.9	2,150	A.
February	50	28	31.1	1,790	A.
March	58	29	37.0	2,280	A.
April	55	28	36.6	2,180	A.
May	53	29	38.1	2,340	A.
June	54	30	37.8	2,250	A.
July	53	30	39.2	2,410	A.
August	55	30	36.9	2,270	A.
September	42	28	35.2	2,090	A.
October	52	30	38.8	2,390	A.
November	54	28	37.2	2,210	A.
December	63	31	42.5	2,610	A.
The year	63	18	37.2	27,000	
1913.					
January	56	0	38.3	2,360	A.
February	47	29	35.9	1,990	A.
March	53	27	36.6	2,250	A.
April	52	31	41.5	2,470	A.
May	52	18	40.5	2,490	A.
June	53	14	40.4	2,400	A.
July	46	31	38.1	2,340	A.
August	48	28	35.7	2,200	A.
September	43	27	32.1	1,910	A.
October	48	0	34.6	2,130	A.
November	45	25	36.7	2,180	B.
December	38	0	29.3	1,800	B.
The year	56	14	36.5	26,500	

NOTE.—Jan. 18, 1913: Gates closed at noon and not opened until the 20th; practically no flow for this period.

May 14, June 4 and 5, 1913, Discharge affected by regulation. Oct. 25–26, no water in ditch; turned in at 4.15 p. m. Oct. 27. Dec. 7, 1913, no water in ditch.

HANAPEPE DITCH AT KOULA, NEAR ELEELE, KAUAI.

Location.—About 4 miles north of Eleele and about 4 miles below Hanapepe Falls.

Records available.—January 1, 1910, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made from cross timber of flume.

Diversions.—Ditch diverts all low-water flow of East Branch of Hanapepe River.

Accuracy.—Records good.

Cooperation.—Gage-height records furnished by Hawaiian Sugar Co.

The following discharge measurement was made by W. V. Hardy.

June 22, 1913: Gage height, 2.84 feet; discharge, 46.2 second-feet.

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Daily discharge, in second-feet, of Hanapepe ditch at Koula, near Eleele, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	50	57	68	52	52	46	51	38	51	37	38	93
2	48	44	37	52	52	43	51	51	51	34	46	82
3	46	44	37	52	52	45	51	44	51	33	47	71
4	44	43	36	52	51	47	51	41	50	30	40	60
5	44	48	36	48	52	48	51	40	51	29	40	49
6	44	50	36	43	52	50	51	39	51	49	51	50
7	44	52	46	41	52	52	51	50	51	49	39	43
8	52	46	38	41	52	51	51	50	45	52	37	36
9	52	45	37	44	52	51	51	46	44	51	49	36
10	52	52	36	50	52	51	46	28	40	50	51	37
11	52	48	34	52	48	51	46	28	39	50	51	44
12	52	45	34	42	50	51	45	38	43	51	51	44
13	52	43	34	52	51	51	51	51	36	51	48	44
14	52	43	34	52	52	51	50	51	38	50	52	44
15	52	43	33	52	52	51	49	47	41	50	52	43
16	52	41	33	49	52	51	46	40	36	50	52	42
17	52	45	51	52	52	50	48	38	35	48	52	42
18	17	52	39	52	52	47	48	37	37	46	52	43
19	34	44	46	52	50	51	44	36	38	43	52	42
20	52	44	49	52	50	45	46	27	44	42	51	41
21	52	45	52	52	48	51	46	51	33	39	49	41
22	52	46	52	52	45	45	44	43	35	40	52	41
23	52	52	49	52	44	46	39	38	33	51	52	40
24	52	44	52	52	49	47	45	38	33	51	52	40
25	52	39	52	52	46	48	51	50	32	50	39	40
26	52	42	52	52	46	51	51	49	31	48	32	39
27	50	40	51	52	44	48	51	39	32	47	34	39
28	48	39	52	52	47	46	45	44	48	46	34	38
29	45	.....	52	52	52	51	50	51	44	42	69	38
30	42	.....	52	52	52	51	43	51	33	39	104	38
31	36	.....	41	.....	49	.....	40	51	.....	40	.....	39

NOTE.—Discharge interpolated for Sundays and holidays when no readings were made.

Monthly discharge of Hanapepe ditch at Koula, near Eleele, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	52	17	47.6	2,930	A.
February	57	39	45.6	2,530	A.
March	52	33	42.6	2,620	A.
April	52	41	50.1	2,980	A.
May	52	44	50.0	3,070	A.
June	52	43	48.9	2,910	A.
July	51	39	47.8	2,940	A.
August	51	27	42.7	2,630	A.
September	51	31	40.9	2,430	A.
October	52	29	44.8	2,750	A.
November	104	32	48.9	2,910	A.
December	93	36	45.8	2,820	A.
The year	104	17	46.3	33,500	

HANAPEPE DITCH AT WEIR NEAR HANAPEPE, KAUAI.

Location.—About 2½ miles northeast of Hanappe at measuring weir maintained by Hawaiian Sugar Co., on the Hanapepe ditch below the last siphon across Hanapepe River.

Records available.—January, 1910, to December 31, 1913; records show amount of water delivered by the ditch at the cane fields.

Gage.—Vertical staff on right bank; zero on gage equals crest of weir.

Control.—Probably permanent.

Discharge measurements.—Computed from formula for a 12-foot, sharp-crested weir with end contractions; checked by current-meter measurements.

Cooperation.—Gage-height records furnished by Hawaiian Sugar Co.

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Daily discharge, in second-feet, of Hanapepe ditch at weir near Hanapepe, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	46.4	43.8	36.3	41.2	41.2	45.1	45.1	37.5	43.8	34.0	40.0	.....
2	46.4	41.2	35.2	41.2	41.2	42.5	45.1	38.8	43.8	35.2	40.0	.....
3	45.1	41.2	35.2	42.5	41.2	40.0	46.4	42.5	43.8	32.8	40.0	.....
4	43.8	40.0	34.0	41.2	40.0	.....	45.1	42.5	43.8	30.4	41.2	.....
5	42.5	41.2	32.8	41.2	30.4	.....	45.1	38.8	42.5	30.4	40.0	.....
6	42.5	42.5	32.8	37.5	37.5	.....	45.1	38.8	42.5	35.2	41.2	40.0
7	42.5	45.1	35.2	36.3	41.2	45.1	45.1	40.0	43.8	40.0	42.5	.....
8	45.1	46.4	38.8	35.2	41.2	46.4	42.5	41.2	42.5	43.8	40.0	21.8
9	46.4	45.1	36.3	35.2	41.2	45.1	42.5	40.0	40.0	45.1	42.5	36.3
10	45.1	43.8	34.0	37.5	41.2	46.4	41.2	38.8	40.0	45.1	46.4	37.5
11	42.5	46.4	32.8	37.5	37.5	46.4	40.0	37.5	37.5	46.4	46.4	38.8
12	43.8	46.4	31.6	38.8	40.0	46.4	40.0	37.5	36.3	46.4	46.4	41.2
13	45.1	42.5	31.6	38.8	27.1	45.1	40.0	38.8	35.2	46.4	49.0	42.5
14	45.1	41.2	31.6	41.2	.....	45.1	41.2	41.2	35.2	45.1	49.0	42.5
15	46.4	41.2	31.6	42.5	.....	45.1	41.2	41.2	35.2	38.8	45.1	42.5
16	47.7	41.2	32.8	42.5	30.4	45.1	41.2	38.8	35.2	42.5	40.0	42.5
17	47.7	40.0	34.0	42.5	46.4	45.1	41.2	36.3	34.0	43.8	46.4	41.2
18	28.2	41.2	40.0	42.5	46.4	45.1	38.8	34.0	32.8	40.0	47.7	40.0
19	.....	43.8	41.2	42.5	46.4	43.8	37.5	32.8	35.2	19.8	49.0	41.2
20	32.8	45.1	42.5	42.5	45.1	42.5	40.0	32.8	34.0	35.2	47.7	40.0
21	47.7	45.1	43.8	42.5	43.8	43.8	40.0	36.3	32.8	38.8	46.4	41.2
22	47.7	42.5	43.8	41.2	42.5	42.5	38.8	37.5	32.8	38.8	.....	41.2
23	47.7	42.5	43.8	41.2	42.5	42.5	37.5	36.3	31.6	41.2	.....	40.0
24	42.5	42.5	42.5	41.2	42.5	41.2	37.5	34.0	30.4	42.5	.....	40.0
25	23.9	43.8	42.5	40.0	43.8	41.2	38.8	35.2	30.4	23.9	40.0	40.0
26	47.7	41.2	43.8	41.2	42.5	43.8	41.2	38.8	30.4	.....	37.5	40.0
27	47.7	40.0	41.2	41.2	42.5	43.8	41.2	38.8	30.4	.....	36.3	38.8
28	46.4	37.5	43.8	41.2	41.2	41.2	41.2	38.8	31.6	.....	36.3	38.8
29	45.1	.....	42.5	42.5	41.2	34.0	40.0	40.0	35.2	30.4	35.2	37.5
30	43.8	.....	40.0	42.5	41.2	45.1	41.2	42.5	32.8	40.0	.....	36.3
31	43.8	.....	40.0	.....	43.8	.....	38.8	43.8	.....	40.0	.....	35.2

NOTE.—Ditch dry Jan. 19; May 14–15; June 4–6; Oct. 26–28; Nov. 22–24 and 30; Dec. 1–5 and 7.

Monthly discharge of Hanapepe ditch at weir near Hanapepe, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January 1–18, 20–31	47.7	23.9	43.6	2,590
February	46.4	37.5	42.7	2,370
March	43.8	31.6	37.7	2,320
April	42.5	35.2	40.5	2,410
May 1–13, 16–31	46.4	27.1	40.8	2,350
June 1–3, 7–30	46.4	34.0	43.7	2,340
July	46.4	37.5	41.3	2,540
August	43.8	32.8	38.4	2,360
September	43.8	30.4	36.5	2,170
October 1–25, 29–31	46.4	19.8	38.3	2,130
November 1–21, 25–29	49.0	35.2	42.8	2,200
December 6, 8–31	42.5	21.8	39.1	1,930
The period	49.0	19.8	40.4	27,700

NOTE.—Mean for month and period is for days when ditch carried water.

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HULEIA RIVER NEAR LIHUE, KAUAI.

Location.—About 300 feet above stone bridge where wagon road from Lihue to the Rice plantation crosses stream; about 4 miles southeast of Lihue.
Records available.—May 8, 1912, to December 31, 1913.
Drainage area.—17.9 square miles.
Gage.—Vertical low-water staff gage; inclined high-water gage.
Control.—Probably permanent.
Discharge measurements.—Made by wading.
Cooperation.—Station is maintained in cooperation with Mr. Charles Rice.
Diversions.—Several above station.
Accuracy.—Records poor.

Daily discharge, in second-feet, of Huleia River near Lihue, Kauai, for 1912–13.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.								
1	.....	7.2	6.4	7.0	7.2	5.8	7.4	9.0
2	.....	7.2	6.2	6.4	6.4	5.5	7.4	87
3	.....	7.2	5.8	6.4	7.2	5.5	7.2	116
4	.....	9.0	5.7	6.2	7.2	5.5	7.2	55
5	.....	11	5.5	6.2	7.2	5.7	7.2	40
6	.....	9.4	5.5	7.0	61	5.5	7.2	31
7	7.4	8.3	5.5	6.4	8.6	5.5	7.2	31
8	7.2	7.4	5.5	5.8	7.2	6.0	7.2	31
9	7.2	7.2	5.5	5.5	7.2	7.0	40	24
10	7.2	7.2	7.6	5.7	7.2	7.2	8.1	20
11	7.2	7.4	9.0	5.5	6.4	7.4	8.1	18
12	7.2	7.4	7.4	5.5	5.8	7.4	7.7	18
13	7.2	7.2	7.0	5.5	5.7	5.8	6.4	17
14	7.2	7.4	40	7.2	5.5	5.8	5.8	16
15	9.0	7.4	26	9.2	5.5	5.5	5.8	15
16	8.1	11	7.4	6.5	5.5	5.5	5.7	14
17	7.4	7.2	9.0	6.4	5.5	5.5	5.7	14
18	7.2	7.2	7.4	5.8	5.5	5.5	7.0	14
19	7.2	7.2	7.2	5.8	6.4	6.4	6.2	12
20	7.0	7.2	7.2	5.8	5.7	7.2	5.7	14
21	6.9	7.2	7.2	5.8	5.5	31	6.4	14
22	6.5	7.0	7.2	6.2	5.5	9.0	7.2	12
23	7.2	6.7	7.0	5.8	5.5	7.2	8.1	55
24	7.4	6.4	7.0	7.2	5.5	7.2	7.4	87
25	7.2	6.4	7.2	7.0	5.5	7.0	7.2	73
26	7.2	6.4	7.2	7.0	5.5	24	6.5	64
27	7.2	6.4	7.2	52	5.5	8.1	5.7	27
28	8.1	6.4	7.0	7.2	5.5	7.2	5.7	16
29	8.5	6.4	7.2	7.0	5.5	9.0	20	14
30	7.6	6.4	7.2	7.2	5.5	9.4	8.1	14
31	7.4	.....	7.2	7.4	.....	8.5	.....	14

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Daily discharge, in second-feet, of Huleia River near Lihue, for 1912–13—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	12	7.2	11	26	11	9.7	14	7.7	14	6.0	12	70
2	11	6.4	11	21	9.7	12	46	12	11	6.0	67	67
3	9.0	5.7	11	18	9.7	191	25	9.7	9.7	6.0	25	73
4	8.1	5.5	10	16	9.7	109	15	7.7	8.1	7.7	20	64
5	7.4	7.2	10	15	9.7	80	12	7.7	7.7	9.9	18	55
6	7.4	174	9.2	15	9.9	61	11	7.7	7.7	11	18	52
7	7.2	58	8.3	15	9.9	67	10	7.7	7.7	12	21	80
8	7.2	40	7.2	18	9.7	124	9.7	7.7	7.7	173	18	70
9	7.4	37	7.2	30	9.7	67	8.7	7.7	7.7	191	18	61
10	8.1	31	6.4	25	9.7	55	8.7	7.7	7.7	44	31	52
11	9.2	17	5.7	23	9.7	28	8.7	7.7	7.7	18	44	28
12	10	12	5.5	23	44	21	7.9	7.7	7.7	14	55	23
13	14	11	7.2	28	101	18	7.7	7.7	7.7	12	35	18
14	14	9.6	8.1	21	55	15	7.7	7.4	7.7	12	25	16
15	18	8.1	7.4	20	94	12	7.7	6.8	7.5	11	67	15
16	18	8.1	6.4	18	28	11	7.7	6.2	7.5	11	18	14
17	22	7.6	5.8	16	25	11	7.7	6.2	7.5	11	39	12
18	24	7.2	5.7	15	23	11	7.7	6.0	7.5	23	39	12
19	24	8.1	5.5	15	22	9.9	7.7	6.0	6.8	11	25	12
20	45	9.0	5.5	14	20	9.7	7.7	6.0	6.8	11	116	12
21	61	11	5.5	12	19	9.7	7.7	6.0	8.1	9.9	132	12
22	55	12	5.5	11	16	9.3	7.7	6.0	7.7	9.9	73	12
23	55	13	272	10	15	8.7	7.7	6.0	6.8	12	94	12
24	52	40	73	9.7	12	8.7	7.7	6.0	6.2	21	64	12
25	17	17	44	9.7	9.7	8.7	7.7	6.0	6.0	74	108	12
26	16	15	25	9.7	10	8.1	7.7	6.0	6.0	70	94	12
27	12	12	23	9.7	9.7	9.7	7.7	6.0	6.0	35	73	12
28	11	12	21	9.7	9.7	11	7.7	6.0	6.0	25	61	12
29	9.0	.....	22	9.7	9.7	11	7.7	14	6.0	16	49	12
30	7.4	.....	23	28	9.7	12	7.7	12	6.0	15	49	12
31	8.1	.....	25	.....	9.7	.....	7.7	9.7	.....	12	.....	12

Monthly discharge of Huleia River near Lihue, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
May 7–31	9.0	6.5	7.40	367	B.
June	11	6.4	7.45	443	B.
July	40	5.5	8.56	526	B.
August	52	5.5	7.92	487	B.
September	61	5.5	7.96	474	B.
October	31	5.5	8.03	494	B.
November	40	5.7	8.42	501	B.
December	116	9.0	31.8	1,960	B.
The period	.....	.....	.....	5,250	
1913.					
January	61	7.2	18.9	1,160	C.
February	174	5.5	21.5	1,190	C.
March	272	5.5	22.4	1,380	C.
April	30	9.7	17.0	1,010	C.
May	101	9.7	21.0	1,290	C.
June	191	8.1	34.0	2,020	C.
July	46	7.7	10.4	640	C.
August	14	6.0	7.6	467	C.
September	14	6.0	7.6	452	C.
October	191	6.0	29.0	1,780	C.
November	132	12	50.3	2,990	C.
December	80	12	30.3	1,860	C.
The year	272	5.5	22.4	16,200	

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HANAMAULU RIVER AT KAPAIA, NEAR LIHUE, KAUAI.

Location.—At wagon-road bridge about 600 feet north of village of Kapaia and about 1.5 miles north of Lihue.

Records available.—September 4, 1911, to December 31, 1913.

Drainage area.—6.41 square miles.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made from lower side of bridge during high water and by wading at low-water stages.

Diversions.—Several above station.

Accuracy.—Records for May and June, good; for all other months, only fair.

Discharge measurements of Hanamaulu River at Kapaia, near Lihue, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec. ft.*
Jan. 29	D. E. Horner	5.30	12.3	May 31	W. V. Hardy	5.69	24.2
May 31	W. V. Hardy	5.54	17.6	May 31	do	5.62	21.6

Daily discharge, in second-feet, of Hanamaulu River at Kapaia, Lihue, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	25	9.7	20	21	6.5	19	5	13	1.8	3.0	47	25
2	30	9.2	14	19	7.5	18	5	13	1.5	3.0	41	20
3	23	8.7	8.5	20	8.1	82	8.5	9.8	4.0	3.0	35	54
4	23	11	3.0	16	7.3	35	11	6.5	3.0	3.0	35	25
5	19	9.7	1.5	9.8	6.5	30	14	5.8	2.5	2.0	30	22
6	15	96	4.2	8.5	5.0	41	10	5.8	4.0	1.0	34	28
7	11	47	3.4	8.5	1.0	35	5	5.6	3.0	.5	22	24
8	11	29	4.6	9.8	5.0	33	4	5.3	2.0	1.0	21	20
9	8.7	24	4.7	11	5.0	31	5	5.0	1.8	21	12	13
10	8.7	18	4.8	8.5	6.5	36	5	3.2	1.8	7.5	3	11
11	7.7	9.8	3.8	9.8	18	25	4	1.5	2.0	2.0	3.5	11
12	12	8.1	3.8	7.5	29	13	5	3.0	2.0	2.5	9.8	11
13	17	7.5	4.6	6.2	41	14	10	3.0	1.8	3.0	16	16
14	12	14	5.0	5.0	30	20	16	1.5	1.9	1.5	11	14
15	11	16	4.6	2.5	41	18	7.5	1.0	2.0	13	3	12
16	9.7	14	5.6	5.0	30	17	13	1.5	2.5	8.5	4	11
17	9.7	13	6.5	16	41	16	17	2.8	3.0	6.5	5	13
18	11	13	5.8	6.5	36	14	9.8	4.0	2.0	25	20	8.5
19	10	20	4.2	5.0	30	25	6.5	1.0	1.5	19	30	9.8
20	9.7	13	4.4	3.8	24	5	7	3.0	1.0	13	61	9.8
21	9.7	16	5.0	2.5	25	1	7.5	1.0	4.2	14	168	7.4
22	15	16	4.6	2.5	30	.5	6.5	1.2	7.5	11	47	5.0
23	12	26	12	5.0	24	(a)	5	1.5	5.8	25	41	8.5
24	12	35	19	7.5	30	(a)	4	1.5	6.5	54	35	9.8
25	11	16	20	8.5	28	(a)	5	1.5	2.0	25	35	9.2
26	12	19	22	6.5	25	(a)	7.5	1.5	2.5	25	34	8.5
27	12	25	20	10	22	5	7.5	1.6	2.5	25	28	7.5
28	9.7	22	12	14	15	12	7.5	3.5	7.8	30	30	7.0
29	12	.....	12	7.5	7.5	8	7.1	16	13	25	24	6.5
30	12	.....	13	7.5	11	5	9.2	19	4.0	44	24	11
31	9.9	.....	19	.....	20	.....	8.5	10	.....	41	.....	11

[a] No discharge June 23–26.

NOTE.—Discharge estimated for Sundays and holidays, on which no observations were made.

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Monthly discharge of Hanamaulu River at Kapaia, near Lihue, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	30	7.7	13.3	818	B.
February	96	7.5	20.2	1,120	B.
March	22	1.5	8.89	547	B.
April	21	2.5	9.03	537	B.
May	41	1.0	19.9	1,220	A.
June	82	(a)	18.6	1,110	A.
July	17	4.0	7.86	483	B.
August	19	1.0	4.95	304	B.
September	13	1.0	3.36	200	B.
October	54	.5	14.8	910	B.
November	168	3.0	30.3	1,800	C.
December	54	5.0	14.5	892	C.
The year	168	(a)	13.7	9,940	

a Channel dry.

SOUTH FORK OF WAILUA RIVER ABOVE WAIEHU FALLS, NEAR LIHUE, KAUAI.

Location.—One mile above Waiehu Falls and about 7 miles northeast of Lihue.
Records available.—December 10, 1911, to December 31, 1913.
Drainage area.—22.4 square miles.
Gage.—Friez water-stage recorder.
Control.—Probably permanent.
Discharge measurements.—Made from cable or by wading.
Diversions.—Several above station.
Accuracy.—Records good except for November and December, when they were only fair.

Discharge measurements of South Fork of Wailua River above Waiehu Falls, near Lihue, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Feb. 23	D. E. Horner	3.61	79.0	May 30	W. V. Hardy	4.12	192
23	do	3.56	76.6				

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Daily discharge, in second-feet, of South Fork of Wailua River above Waiehu Falls, near Lihue, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	87	58	54	127	116	58	192	129	204	15	109	.....
2	66	50	53	118	204	68	453	80	270	19	116	.....
3	56	42	51	113	162	1,150	162	45	225	23	105	.....
4	54	40	45	111	131	295	173	40	98	25	105	.....
5	54	40	42	83	96	204	192	37	91	23	106	.....
6	66	608	40	72	173	189	98	37	201	109	107	.....
7	56	363	124	60	173	135	76	48	138	94	108	.....
8	239	184	98	58	384	109	72	45	80	838	109	.....
9	116	109	74	157	150	127	76	43	66	774	335	.....
10	228	109	64	72	116	116	60	42	58	232	418	128
11	184	120	60	72	295	154	56	40	53	195	792	135
12	292	87	56	48	677	105	60	53	46	164	1,060	130
13	760	74	96	343	663	154	154	87	40	242	925	130
14	242	68	96	256	225	138	83	80	42	167	375	119
15	593	94	53	253	462	120	76	66	56	207	267	116
16	458	116	45	118	288	160	72	46	46	152	253	112
17	181	66	89	239	246	98	66	40	40	157	219	110
18	142	98	64	219	256	107	56	36	37	181	204	112
19	120	133	68	150	152	184	68	38	40	131	962	101
20	98	94	37	98	127	111	107	40	34	107	.....	88
21	144	80	98	94	116	105	70	150	26	189	.....	92
22	449	72	102	78	107	56	54	64	38	253	.....	92
23	187	76	210	138	87	56	48	48	13	127	.....	92
24	359	162	142	80	100	48	54	45	19	219	.....	88
25	154	74	184	288	78	53	138	74	24	162	.....	85
26	105	62	135	120	72	94	242	60	24	131	.....	88
27	105	60	60	83	74	201	120	43	14	109	.....	79
28	64	74	66	83	74	195	76	98	14	213	.....	85
29	100	.....	120	118	76	109	131	278	14	124	.....	66
30	56	.....	98	225	201	113	78	120	17	131	.....	68
31	76	.....	87	.....	76	.....	74	274	.....	131	.....	66

NOTE.—Evidences point to a maximum discharge of about 4,500 second-feet on the night of Nov. 20. No record Nov. 20 to Dec. 9. Discharge interpolated Nov. 5–7.

Monthly discharge of South Fork of Wailua River above Waiehu Falls, near Lihue, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	760	54	190	11,700	A.
February	608	40	115	6,390	A.
March	210	40	85.8	5,280	A.
April	343	48	136	8,090	A.
May	677	72	199	12,200	A.
June	1,150	48	160	9,520	A.
July	453	48	111	6,820	A.
August	278	36	75	4,610	A.
September	270	13	68.9	4,100	A.
October	838	15	182	11,200	A.
November 1–19	1,060	105	351	13,200	B.
December 10–31	135	66	99.2	4,320	B.
The period	.....	.....	.....	97,400	

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HANAMAULU DITCH NEAR LIHUE, KAUAI.

Location.—About 6 miles northwest of Lihue, in flume 180 feet above point where the Kauai Electric Co.'s power line crosses the South Fork of Wailua River.

Records available.—July 1, 1910, to December 31, 1913.

Gage.—Vertical staff installed September 30, 1911, on left side of flume, 18 feet from upper end; new datum.

Control.—Probably permanent.

Discharge measurements.—Made in flume.

Diversion.—Ditch diverts part of flow of the South Fork of Wailua River.

Accuracy.—Records very good.

The following discharge measurement was made by D. E. Horner:
January 31, 1913: Gage height, 2.14 feet; discharge, 38 second-feet.

Daily discharge, in second-feet, of Hanamaulu ditch near Lihue, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	38	35	28	32	32	41	40	38	37	41	24	.....
2	38	38	28	32	32	41	39	36	38	38	23	.....
3	38	44	27	32	41	33	39	36	38	34	24	.....
4	27	42	27	32	41	9.2	40	38	37	32	15	.....
5	27	42	41	30	40	9.2	40	38	37	32	15	.....
6	27	47	41	29	40	9.2	40	56	39	41	15	.....
7	32	41	42	29	41	9.2	40	38	40	47	15	.....
8	32	32	42	29	40	40	40	38	40	47	15	.....
9	35	32	41	32	40	39	39	38	38	33	15	.....
10	35	14	41	32	40	39	39	35	38	32	15	12
11	36	14	41	40	32	38	38	35	38	41	15	12
12	41	32	38	40	32	39	38	35	40	41	11	12
13	41	30	36	41	32	39	36	40	40	35	11	32
14	40	30	36	40	32	39	36	40	36	34	12	32
15	40	30	36	40	22	39	36	40	35	34	15	32
16	39	30	38	40	22	39	36	40	35	36	15	32
17	38	30	38	40	22	39	36	39	35	36	32	32
18	38	30	40	40	15	39	36	39	35	36	32	24
19	38	28	40	40	15	39	36	39	36	24	32	23
20	38	28	40	38	14	35	40	39	36	35	33	23
21	38	28	40	38	29	35	40	40	36	36	13	23
22	47	28	40	36	29	38	35	39	40	36	13	23
23	47	28	42	38	29	38	35	38	40	36	.....	23
24	40	32	24	38	29	38	44	38	40	32	.....	23
25	40	29	40	47	29	41	44	38	40	32	.....	23
26	38	28	40	34	29	40	45	38	39	32	.....	23
27	38	28	32	34	38	40	41	38	38	32	.....	23
28	38	28	32	32	38	40	41	38	38	33	.....	32
29	37	.....	32	32	39	40	36	40	39	32	5	32
30	36	.....	32	32	41	40	36	37	38	32	5	32
31	36	.....	32	.....	41	.....	36	37	.....	32	.....	32

NOTE.—Ditch dry, Nov. 23-28 and Dec. 1-9.

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Monthly discharge of Hanamaulu ditch near Lihue, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	47	27	37.2	2,290	A.
February	47	14	31.4	1,740	A.
March	42	24	36.3	2,230	A.
April	47	29	35.6	2,120	A.
May	41	14	32.1	1,970	A.
June	41	9.2	34.8	2,070	A.
July	45	35	38.6	2,370	A.
August	56	35	38.6	2,370	A.
September	40	35	37.9	2,260	A.
October	47	24	35.3	2,170	A.
November	33	0	14.0	832	A.
December	32	0	17.9	1,100	A.
The year	56	0	32.5	23,500	

LIHUE DITCH NEAR LIHUE, KAUAI.

Location.—About 5 miles northwest of Lihue, at point where Kauai Electric Co.'s power line crosses the ditch.

Records available.—July 1, 1910, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversion.—Ditch diverts part of flow of the South Fork of Wailua River.

Accuracy.—Records fair.

The following discharge measurement was made by W. V. Hardy and D. E. Horner: May 29, 1913: Gage height, 1.42 feet; discharge, 8.93 second-feet.

Daily discharge, in second-feet, of Lihue ditch near Lihue, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.8	7.2	3.8	8.8	10.4	9.2	9.6	9.8	10.2	10.2	8.8	.....
2	8.8	7.2	3.8	8.8	10.4	9.6	9.6	10.0	10.8	10.0	8.8	.....
3	8.4	7.1	3.8	8.0	10.4	3.7	9.2	9.3	10.7	9.6	9.0	.....
4	8.4	6.8	3.8	8.0	10.4	.....	9.5	9.1	10.0	9.4	8.8	.....
5	8.4	6.5	3.8	8.0	10.4	7.4	9.4	9.0	11.2	9.4	8.0	.....
6	8.4	9.6	7.2	7.6	10.4	7.2	9.4	9.0	11.1	9.9	6.6	.....
7	8.4	.....	7.2	7.6	10.4	7.2	9.4	8.8	10.4	10.9	6.6	.....
8	9.6	.....	7.2	7.2	10.4	9.0	9.4	8.8	10.4	12.0	6.6	.....
9	9.6	.....	7.2	7.6	10.4	9.0	9.0	9.8	10.2	10.4	6.5	.....
10	9.8	.....	7.2	7.6	9.6	9.0	9.0	8.9	10.2	9.9	6.5	.....
11	10.0	.....	7.2	8.0	9.6	9.0	8.8	8.8	9.6	11.4	6.7	.....
12	10.4	4.4	7.2	8.0	10.4	9.8	9.2	8.8	9.6	11.4	7.4	.....
13	10.6	4.4	7.2	8.8	8.0	9.8	9.4	10.0	10.4	11.2	7.5	.....
14	8.8	4.0	7.2	8.8	9.6	9.8	9.4	9.6	10.1	10.6	7.4	.....
15	8.8	3.9	7.2	8.8	9.6	9.8	9.4	9.4	10.1	10.6	7.4	.....
16	8.8	3.8	7.6	8.8	3.7	9.8	9.4	10.0	9.6	10.4	7.4	.....
17	8.8	3.8	7.6	8.8	3.7	9.8	9.4	9.6	9.6	10.6	8.0	2.5
18	8.8	3.8	8.0	8.8	3.7	9.8	9.4	9.0	9.6	10.6	8.0	2.5
19	8.4	3.6	8.0	8.8	3.7	9.8	9.4	9.6	9.6	3.7	8.0	2.5
20	8.4	3.6	8.0	8.0	3.7	9.1	9.8	9.8	9.5	10.4	8.0	2.5
21	8.4	4.0	8.4	8.9	3.7	9.0	9.8	10.4	10.1	10.4	8.0	6.9
22	10.4	4.0	8.5	8.0	8.0	9.0	8.9	10.4	10.1	10.9	6.4	6.9
23	8.8	3.9	8.8	8.0	8.0	9.0	8.9	10.2	10.1	10.0	6.4	6.9
24	8.8	4.4	8.0	8.0	8.0	9.0	9.8	9.6	9.8	9.8	6.4	7.0
25	8.0	4.0	8.4	8.8	8.0	9.0	10.4	9.5	9.6	9.9	6.3	7.1
26	7.6	3.8	8.0	10.4	9.6	9.7	10.4	9.6	9.6	10.2	6.2	7.1
27	7.2	3.8	6.8	10.4	9.6	9.7	10.4	9.6	9.4	10.4	6.2	7.2
28	7.2	3.8	6.8	10.4	9.6	9.8	10.0	9.8	10.2	10.0	6.4	7.2
29	7.2	.....	6.8	10.4	8.8	9.8	9.9	10.4	10.0	10.0	6.4	7.2
30	7.2	.....	8.8	10.4	8.9	9.6	9.8	10.8	10.0	9.6	7.0	7.2
31	7.2	.....	8.8	.....	9.6	.....	9.8	10.6	.....	9.6	.....	7.2

NOTE.—Ditch dry Feb. 7-11, June 4, Dec. 1-16.

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Monthly discharge of Lihue ditch near Lihue, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	10.6	7.2	8.66	532	B.
February	9.6	0	3.98	221	B.
March	8.8	3.8	7.04	433	B.
April	10.4	7.2	8.59	511	B.
May	10.4	3.7	8.41	517	B.
June	9.8	0	8.63	513	B.
July	10.4	8.8	9.52	585	B.
August	10.8	8.8	9.61	591	B.
September	11.2	9.4	10.1	601	B.
October	12.0	3.7	10.1	621	B.
November	9.0	6.2	7.26	432	B.
December	7.2	0	2.84	175	B.
The year	12.0	0	7.92	5,730	

NORTH FORK OF WAILUA RIVER NEAR LIHUE, KAUAI.

Location.—About 12 miles north of Lihue and 300 feet below confluence of main and east branches of the stream.

Records available.—August 1 to October 28, 1910; December 28, 1910, to December 31, 1913.

Drainage area.—14.6 square miles.

Gage.—Friez automatic water-stage recorder. Datum changed.

Control.—Fairly permanent.

Discharge measurements.—Made from wire suspension footbridge.

Diversions.—Kanaha ditch diverts part of flow above the station.

Accuracy.—Records fair from January to May; all other records good.

The following discharge measurement was made by W. V. Hardy:
May 29, 1913: Gage height, 0.52 foot; discharge, 39.7 feet.

Daily discharge, in second-feet, of North Fork of Wailua River near Lihue, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	57	27	58	81	39	40	95	42	95	33	54	202
2	54	24	85	62	104	58	267	36	182	30	116	168
3	43	23	84	64	54	551	111	34	150	27	77	220
4	36	23	81	51	40	146	119	32	77	26	57	213
5	38	22	75	35	30	106	104	32	60	25	52	294
6	37	217	66	26	88	109	78	32	111	62	57	200
7	48	132	111	23	85	85	68	35	83	57	84	146
8	130	67	44	23	106	70	56	38	60	368	62	124
9	57	50	22	51	52	92	47	42	54	178	184	111
10	108	49	17	35	41	84	43	36	44	97	213	103
11	111	50	16	43	140	92	42	32	41	120	394	92
12	162	39	15	27	232	63	47	50	42	106	590	90
13	353	35	19	130	177	88	90	47	38	144	394	85
14	128	33	18	156	111	70	63	64	36	111	173	78
15	366	46	22	147	90	64	58	41	38	84	127	76
16	192	43	25	71	84	70	54	63	36	88	106	73
17	102	34	29	153	98	49	44	42	32	74	98	71
18	78	66	32	106	109	54	36	37	32	77	100	71
19	73	52	36	81	73	65	51	49	30	57	262	69
20	64	65	39	59	66	60	77	34	29	49	353	59
21	122	52	43	54	58	55	43	58	34	146	659	62
22	196	43	53	51	49	38	37	42	40	132	424	54
23	85	58	58	61	46	38	36	34	26	78	343	47
24	142	72	229	40	64	34	38	34	28	155	289	44
25	84	42	222	132	49	42	83	45	26	83	504	42
26	70	35	172	49	42	66	108	39	26	65	420	42
27	65	31	92	38	45	97	71	35	26	66	257	41
28	54	30	72	34	47	114	40	88	58	112	218	40
29	47	.....	65	37	47	69	85	171	30	68	570	36
30	42	.....	53	82	87	98	43	88	29	69	303	32
31	39	.....	50	.....	45	.....	38	116	.....	63	.....	35

Discharge estimated Mar. 15–20.

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Monthly discharge of North Fork of Wailua River near Lihue, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	366	36	103	6,330	B.
February	217	22	52.1	2,890	B.
March	229	15	64.6	3,970	B.
April	156	23	66.7	3,970	B.
May	232	30	77.3	4,750	B.
June	551	34	88.9	5,290	A.
July	267	36	70.1	4,310	A.
August	171	32	50.6	3,110	A.
September	182	26	53.1	3,160	A.
October	368	25	91.9	5,650	A.
November	659	52	251	14,900	A.
December	224	32	95.2	5,850	A.
The year	659	15	88.7	64,200	

KANAHA DITCH NEAR LIHUE, KAUAI.

Location.—About 9 miles north of Lihue and about 500 feet above the point where the Kauai Electric Co.'s power line crosses the ditch.

Records available.—August 6, 1910, to December 31, 1913.

Gage.—Vertical staff; datum changed.

Discharge measurements.—Made in flume 100 feet above gage.

Diversion.—Diverts part of flow of North Fork of Wailua River.

Accuracy.—Records good.

Discharge measurements of Kanaha ditch near Lihue, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec. ft.*
May 28 [a]	D. E. Horner	2.02	27.9
May 30 [a]	W. V. Hardy	2.43	33.2

[a] Measurements refer to gage installed May 28.

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Daily discharge, in second-feet, of Kanaha ditch near Lihue, Kauai, for 1912–13.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.												
1	24	21	25	25	28	28	28	27	35	31	30	32
2	24	20	25	24	27	27	28	30	35	30	31	35
3	.....	20	28	24	28	27	28	30	33	31	31	33
4	.....	20	27	25	33	27	28	30	33	31	31	11
5	.....	20	25	28	30	27	28	30	33	34	35	11
6	.....	19	25	27	28	28	28	30	35	32	35	11
7	.....	19	28	30	27	28	31	31	33	32	33	10
8	.....	19	27	30	30	28	33	33	33	33	33	11
9	.....	25	28	30	28	28	28	33	33	32	35	11
10	.....	24	28	28	27	28	33	33	33	32	34	22
11	.....	24	31	27	26	28	33	33	33	33	32	22
12	.....	24	31	27	25	28	33	33	30	33	30	22
13	.....	24	31	25	25	28	33	33	30	32	30	22
14	.....	22	30	25	28	28	35	35	30	31	30	21
15	.....	22	28	25	28	28	31	31	31	31	33	21
16	.....	22	27	27	28	28	28	33	32	30	29	21
17	.....	24	27	31	28	28	33	30	30	34	29	27
18	.....	24	26	22	28	27	30	31	28	33	32	27
19	.....	24	25	21	28	27	31	31	28	34	33	30
20	.....	24	25	21	28	27	31	31	31	34	34	31
21	.....	22	28	16	28	28	31	31	31	34	34	29
22	21	25	28	16	28	30	28	30	32	34	35	30
23	22	25	28	16	28	30	28	30	31	34	.....	29
24	22	25	22	25	29	28	28	30	30	33	.....	30
25	22	28	24	28	29	27	30	35	28	33	.....	28
26	21	28	24	24	29	27	31	33	28	35	11	27
27	21	28	24	27	29	30	31	33	28	34	11	27
28	21	25	22	27	31	28	31	33	27	34	12	24
29	19	25	22	28	31	27	30	33	31	33	33	22
30	19	.....	25	28	30	27	33	35	32	31	30	22
31	19	.....	25	.....	28	.....	28	35	.....	32	.....	22
1913.												
1	22	24	12	31	31	26	32	29	34	28	31	.....
2	22	24	12	31	33	30	34	31	31	28	31	.....
3	21	23	12	31	33	30	32	31	31	26	31	.....
4	22	23	11	31	33	26	31	28	31	26	26	.....
5	22	22	11	30	32	26	31	28	31	26	25	.....
6	22	25	24	29	33	28	31	28	34	30	25	.....
7	22	30	33	28	32	24	31	28	32	32	25	.....
8	28	28	31	28	32	25	31	28	31	35	25	.....
9	28	16	28	31	31	29	30	31	30	32	25	.....
10	29	16	28	31	30	25	30	28	30	30	26	.....
11	30	16	28	30	33	25	28	26	30	30	26	.....
12	31	16	28	30	33	25	32	26	28	32	29	.....
13	33	16	28	31	33	31	32	32	31	34	26	11
14	30	15	28	31	30	31	32	32	30	34	30	11
15	31	15	28	31	30	31	32	32	29	32	30	11
16	33	15	28	31	30	31	30	34	29	32	30	11
17	28	15	28	31	27	28	30	26	29	32	30	11
18	24	13	28	31	25	29	30	26	28	31	30	11
19	22	12	30	31	24	31	30	29	28	31	30	14
20	22	12	31	30	24	31	31	30	28	31	30	14
21	22	12	31	30	21	31	31	34	28	32	29	14
22	35	12	33	28	21	31	28	34	29	32	19	14
23	31	12	33	30	21	31	29	32	28	32	19	16
24	31	15	31	31	21	29	36	31	28	32	19	16
25	28	12	32	33	21	31	36	31	28	32	18	16
26	28	12	31	33	27	31	36	29	28	32	18	16
27	27	12	30	31	25	31	34	29	26	32	18	16
28	27	12	30	31	26	32	32	29	27	32	18	20
29	24	.....	29	31	29	32	31	35	29	32	18	23
30	23	.....	29	33	29	32	31	34	30	31	18	24
31	22	.....	29	.....	29	.....	31	34	.....	31	.....	24

NOTE.—Channel dry Jan. 3–21, Nov. 23–25, 1912; Dec. 1–12, 1913.

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Monthly discharge of Kanaha ditch near Lihue, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
January	24	0	8.23	506	A.
February	28	19	23.2	1,330	A.
March	31	22	26.4	1,620	A.
April	30	16	25.2	1,500	A.
May	33	25	28.3	1,740	A.
June	30	27	27.8	1,650	A.
July	39	28	30.9	1,900	A.
August	39	27	33.3	2,050	A.
September	35	27	31.2	1,860	A.
October	35	30	32.6	2,000	A.
November	35	0	26.9	1,600	A.
December	35	10	23.2	1,430	A.
The year	39	0	26.5	19,200	
1913.					
January	35	21	26.4	1,620	A
February	30	12	17.0	944	A.
March	33	11	26.6	1,640	A.
April	33	28	30.6	1,820	A.
May	33	21	27.4	1,680	A.
June	32	24	29.1	1,730	A.
July	36	28	31.5	1,940	A.
August	35	26	30.2	1,860	A.
September	34	26	29.5	1,760	A.
October	35	26	31.0	1,910	A.
November	31	18	25.2	1,500	A.
December 13-31	24	0	9.45	581	A.
The year	36	0	26.2	19,000	

EAST BRANCH OF NORTH FORK OF WAILUA RIVER, NEAR LIHUE, KAUAI.

Location.—About 8 miles north of Lihue, 600 feet above gaging station on the North Fork of Wailua, and 400 feet above the confluence of the North and East branches of the North Fork of Wailua River.

Records available.—July 27, 1912, to December 31, 1913.

Drainage area.—6.2 square miles.

Gage.—Inclined staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Accuracy.—Records fair except for November, when broken records were obtained.

Discharge measurements of East Branch of North Fork of Wailua River near Lihue, Kauai, in 1913.

Date.	Hydrographer.	Gage height	Discharge.
		Feet.	*Sec.-ft.*
Jan. 19	D. E. Horner	6.50	46.7
May 29	W. V. Hardy	6.30	30.7

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Daily discharge, in second-feet, of East Branch of North Fork of Wailua River, near Lihue, Kauai, for 1912–13.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.							1912.						
1	.....	26	32	41	34	66	16	.....	36	20	24	26	32
2	.....	25	41	82	28	49	17	.....	32	20	32	23	32
3	.....	24	36	82	26	31	18	.....	25	20	28	26	32
4	.....	23	32	26	37	14	19	.....	28	20	43	39	39
5	.....	22	32	24	48	14	20	.....	26	24	32	32	55
6	.....	32	52	22	41	100	21	.....	24	23	66	48	14
7	.....	36	36	23	36	69	22	.....	24	23	41	63	179
8	.....	32	30	36	38	68	23	.....	24	20	36	76	69
9	.....	32	32	28	59	56	24	.....	23	19	34	30	65
10	.....	26	26	26	96	55	25	.....	26	18	33	28	62
11	.....	24	24	100	34	53	26	.....	32	17	39	26	58
12	.....	24	24	36	26	51	27	28	52	17	34	24	52
13	.....	24	24	30	26	43	28	28	32	18	37	36	50
14	.....	28	23	28	24	41	29	28	32	19	39	47	24
15	.....	32	21	26	26	30	30	36	41	20	40	59	36
							31	27	36	.....	39	.....	36

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	34	30	23	41	41	35	41	29	42	18	70	133
2	32	29	24	41	36	24	47	26	42	18	110	123
3	32	28	23	41	36	42	53	22	43	17	30	113
4	30	26	18	36	32	69	59	24	44	17	32	102
5	39	26	18	32	41	52	56	24	36	16	30	92
6	30	24	20	25	66	45	36	25	40	36	32	82
7	28	32	28	30	59	43	34	24	44	56	44	82
8	32	41	32	36	41	40	32	24	32	50	36	62
9	32	33	21	36	32	46	30	32	28	43	27	55
10	39	41	31	41	32	48	28	24	24	36	32	52
11	46	36	24	26	34	42	32	26	26	34	43	50
12	74	36	24	24	52	41	32	24	24	46	43	48
13	71	27	23	26	46	46	35	35	24	45	44	41
14	66	26	24	63	41	41	31	36	24	44	44	112
15	79	26	24	100	41	36	30	38	24	42	44	34
16	59	35	18	83	46	52	26	41	23	41	45	32
17	55	28	20	66	52	35	24	27	23	36	61	30
18	52	28	23	52	58	34	30	32	20	35	76	28
19	41	28	26	52	41	34	30	26	20	33	92	27
20	41	28	28	44	35	32	26	24	20	32	108	26
21	41	32	29	41	34	28	36	35	32	32	123	24
22	24	31	30	44	32	26	26	24	26	41	139	26
23	56	30	32	46	32	28	24	27	20	40	154	24
24	100	32	24	43	32	26	29	30	19	36	170	24
25	52	28	17	41	32	26	24	24	19	34	151	24
26	40	26	12	32	30	26	52	24	18	33	132	24
27	41	24	28	32	30	32	32	24	18	32	114	24
28	32	23	44	32	28	58	32	24	31	37	95	20
29	32	.....	41	41	24	30	32	56	26	36	82	23
30	31	.....	34	52	17	43	30	46	22	32	143	20
31	30	.....	41	.....	24	.....	26	41	.....	30	.....	20

NOTE.—Discharge estimated for following days on which no gage heights were recorded: 1912: Aug. 14; Sept. 13; Nov. 4, 21, 25, 28, and 29; Dec. 2, 3, 11, 24, and 25; 1913: Jan. 1, 10, and 30; Feb. 3, 7, and 19; Mar. 17–19, 24, and 27; Apr. 4, 7, 14, 16, and 22; June 3 and 18; July 2, 3, and 28; Aug. 15 and 23; Sept. 1–3, 6, 15, 22, 29, and 30; Oct. 6, 15, 20, and 26; Nov. 1, 12–14, 17–23, and 25–27; Dec. 1–5, 16, 19, and 25.

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Monthly discharge of East Branch of North Fork of Wailua River near Lihue, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
July 27–31	36	27	29.4	291	B.
August	52	22	29.2	1,800	B.
September	52	17	25.4	1,510	B.
October	100	22	39.0	2,400	B.
November	96	23	38.7	2,300	B.
December	179	14	50.5	3,110	B.
1913.					
January	100	28	44.9	2,760	B.
February	41	23	29.8	1,660	B.
March	44	12	25.9	1,590	B.
April	100	24	43.3	2,580	B.
May	66	17	38.0	2,340	B.
June	69	24	38.7	2,300	B.
July	59	24	34.0	2,090	B.
August	56	22	29.6	1,820	B.
September	44	18	27.8	1,650	B.
October	56	16	34.8	2,140	B.
November	170	27	78.2	4,650	C.
December	133	20	50.9	3,130	B.
The year	170	12	39.7	28,700	

KONOHIKI STREAM AT MAKAKUALELE WEIR (MAUKA), NEAR KEALIA, KAUAI.

Location.—About 5 miles southwest of Kealia.

Records available.—April 1, 1911, to December 31, 1913.

Gage.—Vertical staff.

Discharge measurements.—Made with 3-foot sharp-crested weir.

Cooperation.—Station maintained and daily-discharge record furnished by the Makee Sugar Co.

Discharge, in million gallons per day, of Konohiki Stream at Makakualele weir (mauka), near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.38	0.38	0.45	0.54	0.49	0.54	0.86	0.67	0.67	0.58	0.62	1.95
2	.38	.38	.45	.54	.49	.54	.86	.67	.67	.58	.62	2.79
3	.38	.38	.45	.54	.49	3.79	.86	.67	1.16	.54	.62	3.01
4	.38	.38	.41	.49	.49	2.79	.86	.67	.96	.58	.62	3.01
5	.38	.38	.41	.49	.49	2.21	.86	.67	.67	.58	.62	2.29
6	.38	1.17	.41	.49	.49	1.64	.81	.67	.67	.49	.71	2.09
7	.38	.96	.41	.49	.54	1.28	.81	.62	.67	.49	.71	2.09
8	.38	.49	.41	.49	.54	1.17	.81	.62	.67	.49	.71	2.71
9	.38	.45	.41	.49	.54	1.40	.81	.62	.67	.62	.71	2.71
10	.38	.41	.41	.49	.49	1.17	.81	.62	.62	.62	.62	2.21
11	.38	.45	.41	.49	.49	1.06	.81	.62	.62	.54	.58	2.09
12	.38	.41	.41	.49	1.06	1.01	.81	.62	.62	.54	.58	2.02
13	.38	.41	.41	.49	1.17	1.01	.96	.71	.58	.54	.58	1.89
14	.38	.41	.45	.49	.91	.96	.86	.71	.58	.54	.58	1.83
15	.38	.41	.41	.54	.67	.96	.86	.71	.58	.54	.54	1.83
16	.38	.41	.41	.49	.58	.96	.81	.71	.58	.54	.54	1.76
17	.38	.41	.41	.49	.62	.96	.81	.67	.58	.86	.54	1.64
18	.38	.67	.41	.49	.58	.96	.81	.67	.58	.71	.54	1.52
19	.38	.58	.41	.49	.58	.96	.81	.67	.58	.71	.62	1.52
20	.38	.45	.41	.49	.49	.96	.81	.67	.58	.67	.76	1.64
21	.38	.45	.41	.49	.49	.86	.81	.67	.58	.58	18.3	1.52
22	.38	.45	.41	.49	.49	.86	.81	.58	.58	.58	6.47	1.52
23	.38	.45	.58	.49	.58	.86	.76	.58	.58	.62	2.57	1.46
24	.38	.49	1.34	.49	.58	.86	.....	.62	.58	.76	2.57	1.46
25	.38	.45	.91	.49	.58	.86	.....	.67	.58	.67	2.36	1.46
26	.38	.45	.81	.49	.58	.86	.....	.58	.58	.67	1.95	1.40
27	.38	.45	.71	.49	.54	.96	.....	.67	.58	.62	1.95	1.40
28	.38	.45	.62	.49	.54	.96	.71	.67	.76	.62	1.95	1.34
29	.38	.....	.62	.49	.54	.86	.71	.67	.58	.76	.62	1.34
30	.38	.....	.62	.49	.54	.86	.67	.67	.58	.67	.62	1.34
31	.34	.....	.54	.....	.54	.....	.67	.67	.....	.67	.....	1.34

NOTE.—No record July 24–27.

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Monthly discharge of Konohiki Stream at Makaualele weir (mauka), near Kealia, Kauai, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	0.38	0.34	0.38	36
February	1.17	.38	.47	49
March	1.34	.41	.51	49
April	.54	.49	.50	46
May	1.17	.49	.59	56
June	3.79	.54	1.17	108
July 1-23, 28-31	.86	.67	.81	67
August	.71	.58	.66	62
September	1.16	.58	.64	59
October	.86	.49	.61	58
November	18.3	.54	1.72	158
December	3.01	1.34	1.88	179
The period (361 days)	18.3	.34	.83	919

NOTE.—Mean for July is for 27 days.

SOUTH FORK OF KAEHULUA STREAM AT WAINAMUAMU WEIR, NEAR KEALIA, KAUAI.

Location.—About 5 miles southwest of Kealia.

Records available.—April 1, 1911, to December 31, 1913.

Gage.—Vertical staff.

Discharge measurements.—Made with a 3-foot sharp-crested weir.

Cooperation.—Station maintained and daily-discharge record furnished by the Makee Sugar Co.

Discharge, in million gallons per day, of South Fork of Kaehulua Stream at Wainamuamu weir, near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.30	0.27	0.30	0.30	0.30	0.27	0.38	1.64	0.58	0.49	0.62	0.58
2	.30	.27	.30	.30	.30	.27	.38	.91	.67	.49	.67	.58
3	.30	.27	.30	.30	.30	1.34	.38	.38	.67	.45	.58	.58
4	.30	.27	.30	.30	.30	1.06	.38	.38	.67	.41	.58	.58
5	.30	.27	.30	.30	.30	.86	.38	.38	.58	.41	.58	.58
6	.30	.58	.30	.30	.30	.76	.34	.38	.58	.41	.58	.58
7	.30	.49	.30	.30	.30	.49	.....	2.29	.58	.45	.58	.58
8	.30	.41	.30	.30	.30	.49	.....	.38	.58	.45	.58	.58
9	.30	.38	.30	.30	.30	.45	.....	.38	.58	.58	.58	.58
10	.30	.38	.30	.30	.30	.45	.....	.38	.58	.58	.58	.58
11	.27	.34	.30	.30	.30	.41	.....	.38	.58	.58	.58	.58
12	.27	.34	.30	.30	.45	.41	.....	.38	.58	.58	.58	.58
13	.27	.34	.30	.30	.49	.41	.41	.38	.54	.58	.58	.58
14	.27	.34	.30	.30	.81	.38	.34	.58	.54	.58	.58	.58
15	.27	.34	.30	.30	.34	.38	.....	.58	.54	.58	.58	.58
16	.27	.34	.30	.30	.30	.38	.....	.58	.54	.58	.58	.58
17	.27	.30	.30	.30	.30	.38	.....	.58	.54	.96	.58	.58
18	.27	.38	.30	.30	.30	.38	.....	.49	.54	.76	.58	.58
19	.27	.34	.30	.30	.30	.38	.....	.45	.54	.76	.58	.58
20	.27	.30	.30	.30	.30	.38	.....	.45	.54	.71	.58	.58
21	.27	.30	.30	.30	.30	.38	.....	.45	.54	.62	.58	.58
22	.27	.30	.30	.30	.30	.38	.....	.62	.54	.58	.58	.58
23	.27	.30	.41	.30	.30	.38	.30	.62	.49	.67	.58	.58
24	.27	.34	.58	.30	.30	.38	1.17	.62	.49	.81	.58	.58
25	.27	.30	.54	.30	.30	.38	.34	.62	.49	.71	.58	.58
26	.27	.30	.41	.30	.30	.38	.34	.58	.49	.71	.58	.58
27	.27	.30	.38	.30	.27	.38	.34	.58	.58	.67	.58	.58
28	.27	.30	.34	.30	.27	.38	1.70	.58	.62	.58	.58	.58
29	.27	.....	.34	.30	.27	.38	.34	.58	.49	.71	.58	.58
30	.27	.....	.34	.30	.27	.38	.34	.58	.49	.76	.58	.58
31	.27	.....	.30	.30	.27	.....	.30	.58	.....	.76	.....	.58

NOTE.—No record July 7-12, 15-22.

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Monthly discharge of South Fork of Kaehulua Stream at Wainamuamu weir, near Kealia, Kauai, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	0.30	0.27	0.28	27
February	.58	.27	.34	29
March	.58	.30	.33	31
April	.30	.30	.30	28
May	.81	.27	.32	31
June	1.34	.27	.46	42
July 1-6, 13-14, 23-31	1.70	.30	.48	25
August	2.29	.38	.61	58
September	.67	.49	.56	52
October	.96	.41	.61	58
November	.67	.57	.58	54
December	.58	.58	.58	55
The period (351 days)	2.29	.27	.45	490

KAEHULUA STREAM AT KUHINOA WEIR, NEAR KEALIA, KAUAI.

Location.—About 3 miles southwest of Kealia.

Records available.—May 1, 1911, to December 31, 1913.

Gage.—Vertical staff.

Discharge measurements.—Made with 6.5-foot sharp-crested weir.

Cooperation.—Station maintained and daily-discharge record furnished by Makee Sugar Co.

Discharge, in million gallons per day, of Kaehulua Stream at Kuhinoa weir, near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.04	0.12	0.44	0.12	0.44	0.12	0.21	0.12	0.11	0.07	0.44	6.52
2	.04	.12	.12	.12	.38	.12	.26	.12	.11	.07	.44	4.96
3	.04	.12	.12	.12	.26	9.14	.81	.12	.12	.07	.32	6.52
4	.04	.12	.12	.12	.21	9.14	.66	.12	.12	.07	.26	5.72
5	.07	.12	.12	.12	.12	11.1	.58	.12	.12	.07	.26	3.55
6	.07	.44	.12	.12	.12	3.96	.73	.12	.12	.12	.26	3.55
7	.11	.44	.12	.12	.26	3.82	.44	.12	.12	.12	.44	3.55
8	.12	.44	.12	.12	.12	1.26	.38	.12	.12	.12	.51	4.96
9	.07	.44	.12	.12	.21	1.16	.26	.12	.12	.12	.51	4.23
10	.12	.44	.12	.12	.21	.90	.26	.12	.12	.12	.44	4.38
11	.12	.44	.12	.04	.21	.58	.26	.12	.11	.12	.32	3.82
12	.12	.44	.12	.04	.81	.44	.26	.11	.11	.12	.26	2.91
13	.12	.44	.12	.04	2.54	.38	.26	.11	.07	.12	.44	3.55
14	.12	.44	.12	.04	2.08	.32	.26	.07	.07	.12	.44	3.55
15	.12	.44	.12	.11	1.86	.38	.21	.07	.07	.12	.58	3.55
16	.26	.12	.12	.11	1.86	.51	.21	.07	.07	.12	.58	2.91
17	.44	.12	.12	.04	1.86	.32	.12	.07	.07	.32	.58	2.91
18	.44	.12	.12	.04	.81	.32	.12	.04	.07	.26	.58	3.55
19	.12	.12	.12	.07	.81	.32	.12	.04	.07	.26	.73	6.52
20	.12	.12	.12	.07	1.16	.32	.12	.04	.07	.21	1.07	3.55
21	.12	.12	.12	.07	.44	.32	.12	.04	.07	.21	39.7	3.55
22	.12	.12	.12	.12	.21	.26	.21	.04	.07	.21	14.0	3.55
23	.58	.24	.44	.12	.12	.21	.12	.04	.07	.44	6.52	3.55
24	.12	.24	.44	.32	.12	.32	.12	.04	.07	.44	6.52	2.91
25	.12	.24	.44	.26	.12	.26	.12	.04	.04	.44	4.96	2.91
26	.12	.24	.44	.26	.12	.21	.12	.04	.04	.44	1.26	2.91
27	.12	.24	.44	.21	.12	.12	.12	.04	.04	.44	.81	.44
28	.12	.24	.44	.21	.12	.12	.12	.04	.12	.44	.81	.44
29	.12	.....	.44	.21	.12	.12	.12	.04	.12	.58	.81	.44
30	.12	.....	.12	.32	.12	.21	.12	.04	.12	.58	.81	.44
31	.12	.....	.12	.....	.12	.....	.12	.04	.....	.58	.....	.44

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Monthly discharge of Kaehulua Stream at Kuhinoa weir, near Kealia, Kauai, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	0.58	0.04	0.14	13
February	.44	.12	.26	22
March	.44	.12	.20	19
April	.32	.04	.13	12
May	2.54	.12	.58	55
June	11.1	.12	1.56	144
July	.81	.12	.26	25
August	.12	.04	.08	8
September	.12	.04	.09	8
October	.58	.07	.24	23
November	39.7	.26	2.86	263
December	6.52	.44	3.43	326
The year	39.7	.04	.82	918

NORTH FORK OF KEAHULUA STREAM AT KAINAHOLA WEIR, NEAR KEALIA, KAUAI.

Location.—About 3 miles southwest of Kealia.

Records available.—April 1, 1911, to December 31, 1913.

Gage.—Vertical staff.

Discharge measurements.—Made with 3-foot sharp-crested weir.

Cooperation.—Station maintained and daily-discharge record furnished by the Makee Sugar Co.

Daily discharge, in million gallons per day, of North Fork of Kaehulua Stream at Kainahola weir, near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.81
2	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.58
3	.41	.41	.41	.41	.41	.96	.41	.41	.49	.41	.41	.62
4	.41	.41	.41	.41	.41	.58	.41	.41	.41	.41	.41	1.01
5	.41	.41	.41	.41	.41	.58	.41	.41	.41	.41	.41	.81
6	.41	.49	.41	.41	.41	.49	.41	.41	.41	.41	.41	.58
7	.41	.54	.41	.41	.41	.49	.41	.41	.41	.41	.41	.49
8	.41	.45	.41	.41	.41	.41	.41	.41	.41	.41	.41	.49
9	.41	.41	.41	.41	.49	.41	.41	.41	.41	.41	.49	.41
10	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41
11	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.41	.41
12	.41	.41	.38	.49	.45	.41	.41	.41	.41	.41	.41	.41
13	.41	.41	.38	.49	.41	.41	.41	.41	.41	.41	.41	.41
14	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.41	.41
15	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.41	.41
16	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.41	.41
17	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.41	.41
18	.41	.58	.38	.41	.41	.41	.41	.41	41	.41	.41	.41
19	.41	.45	.38	.41	.41	.41	.41	.41	.41	.41	.41	.41
20	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.58	.41
21	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.67	.41
22	.41	.41	.38	.41	.41	.41	.41	.41	.41	.41	.62	.41
23	.41	.41	.58	.41	.41	.41	.41	.41	.41	.41	.58	.41
24	.41	.41	.49	.41	.41	.41	.41	.41	.41	.41	.58	.41
25	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.58	.41
26	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.49	.41
27	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41
28	.41	.41	.41	.41	.41	.41	.41	.41	.58	.41	.41	.41
29	.41	.....	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41
30	.41	.....	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41
31	.41	.....	.41	.41	.41	.....	.41	.41	.....	.41	.....	.41

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Monthly discharge of North Fork of Kaehulua Stream at Kainahola weir, near Kealia, Kauai, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	0.41	0.41	0.41	39
February	.58	.41	.43	37
March	.58	.38	.41	39
April	.49	.41	.42	39
May	.49	.41	.41	39
June	.96	.41	.44	41
July	.41	.41	.41	39
August	.41	.41	.41	39
September	.58	.41	.42	39
October	.41	.41	.41	39
November	.67	.41	.45	41
December	1.01	.41	.48	46
The year	1.01	.38	.42	477

KAPAA RIVER NEAR KEALIA, KAUAI.

Location.—About 1 mile above intake of Kapahi ditch and 5 miles northwest of Kealia.

Records available.—July 23, 1910, to December 31, 1913.

Drainage area.—3.6 square miles.

Gage.—Vertical staff.

Control.—Fairly permanent.

Discharge measurements.—Made from wire suspension footbridge or by wading.

Accuracy.—Records good except for November and December, when records were fair.

Cooperation.—Station is maintained in cooperation with the Makee Sugar Co.

The following discharge measurement was made by W. V. Hardy:

May 20, 1913: Gage height, 1.54 feet; discharge, 14.1 second-feet.

Daily discharge, in second-feet, of Kapaa River near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	17	12	12	22	13	16	23	14	32	13	15	27
2	20	12	12	20	30	153	54	15	20	13	34	21
3	15	12	12	23	14	155	24	14	44	13	24	220
4	13	12	11	20	16	78	33	13	18	13	18	139
5	13	12	11	16	13	38	33	13	17	12	18	42
6	14	158	12	14	32	38	19	13	32	23	16	60
7	18	46	24	13	23	24	17	17	20	37	36	38
8	28	21	14	13	51	20	16	16	17	30	22	29
9	19	16	13	24	27	42	17	21	16	48	115	22
10	20	14	12	17	17	23	14	16	15	17	48	20
11	17	15	11	22	16	32	15	14	14	20	44	18
12	42	13	11	14	48	20	19	17	16	19	64	17
13	96	13	13	31	115	23	33	23	14	26	60	17
14	26	12	12	45	36	22	24	41	14	19	26	16
15	21	13	11	35	21	21	17	19	14	20	20	15
16	51	14	14	20	32	24	17	31	14	18	21	13
17	21	13	13	52	39	18	16	18	13	16	21	13
18	17	86	13	29	33	18	14	14	13	36	31	14
19	16	36	13	23	19	16	19	14	13	17	71	13
20	14	36	16	17	16	14	19	14	13	15	127	13
21	64	18	19	17	15	14	17	21	15	38	631	13
22	46	18	26	17	14	14	14	17	14	168	121	13
23	19	32	95	19	13	14	14	16	13	29	62	13
24	20	28	105	15	16	13	16	17	13	20	76	12
25	18	16	121	19	16	13	22	21	12	20	127	12
26	16	14	62	14	14	22	28	21	12	18	67	12
27	16	13	24	13	13	49	27	16	12	16	51	12
28	14	13	20	13	16	37	16	22	48	41	39	12
29	14	.....	18	15	14	20	34	44	13	21	26	12
30	13	.....	18	15	28	37	18	34	14	17	62	12
31	12	.....	18	.....	15	.....	17	30	.....	16	.....	12

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Monthly discharge of Kapaa River near Kealia, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	96	12	24.2	1,490	A.
February	158	12	25.6	1,420	A.
March	121	11	25.4	1,560	A.
April	52	13	20.9	1,240	A.
May	115	13	25.3	1,560	A.
June	155	13	34.3	2,040	A.
July	54	14	21.5	1,320	A.
August	44	13	19.9	1,220	A.
September	48	12	17.8	1,060	A.
October	168	12	26.7	1,640	A.
November	631	15	69.8	4,150	B.
December	220	12	29.1	1,790	B.
The year	631	11	28.2	20,500	

AKULIKULI SPRING NEAR KEALIA, KAUAI.

Location.—About 5 miles west of Kealia.

Records available.—April 1, 1911, to December 31, 1913.

Gage.—Vertical staff.

Discharge measurements.—Made with a 3-foot sharp-crested weir.

Cooperation.—Station maintained and daily-discharge record furnished by the Makee Sugar Co.

Discharge, in million gallons per day, of Akulikuli Spring near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.67	0.62	0.67	0.67	0.67	0.58	0.67	0.67	0.76	0.67	0.67	1.06
2	.67	.62	.67	.67	.67	.58	1.76	.67	.71	.67	.67	.81
3	.67	.62	.62	.67	.67	4.22	1.34	.67	1.64	.67	.67	1.64
4	.67	.62	.58	.67	.67	3.63	1.34	.67	1.28	.62	.67	1.95
5	.67	.62	.58	.67	.67	2.64	.96	.67	.67	.58	.67	1.34
6	.67	1.59	.58	.67	.67	1.95	.81	.67	.67	.58	.67	1.17
7	.67	2.08	.58	.67	1.06	1.06	.81	.67	.67	.67	.76	1.06
8	.67	.81	.58	.67	.81	.96	.67	.67	.67	.67	.67	.96
9	.67	.67	.58	.67	1.34	1.06	.67	.67	.67	.67	.71	.81
10	.67	.67	.58	.67	.81	.81	.67	.67	.67	.67	.67	.81
11	.67	.67	.58	.67	.67	.71	.67	.67	.67	.67	.67	.81
12	.76	.67	.58	.67	1.34	.67	.67	.67	.67	.67	.67	.76
13	.71	.67	.58	.67	1.52	.67	.81	.67	.67	.67	.67	.67
14	.71	.67	.58	.67	.81	.67	.76	.67	.67	.67	.67	.67
15	.67	.67	.58	.96	.81	.67	.67	.81	.67	.67	.67	.67
16	3.39	.67	.58	.76	.81	.67	.67	.81	.67	.67	.67	.67
17	1.06	.67	.58	1.52	.91	.67	.67	.76	.67	.67	.67	.67
18	.76	2.21	.58	.86	.81	.67	.67	.67	.67	.67	.67	.67
19	.76	.91	.58	.67	.71	.67	.67	.67	.62	.67	.67	.67
20	.67	.81	.58	.67	.67	.67	.67	.67	.62	.67	.81	.67
21	.71	.67	.58	.67	.67	.67	.67	.67	.62	.67	2.43	.67
22	.71	.67	.71	.67	.67	.67	.67	.67	.62	.67	1.34	.67
23	.67	.71	2.36	.67	.67	.67	.67	.67	.62	.76	1.06	.67
24	.67	.96	1.06	.67	.67	.67	.67	.67	.62	.67	.96	.67
25	.67	.67	.81	.67	.67	.67	.67	.67	.62	.67	1.06	.67
26	.67	.67	.81	.67	.67	.67	.67	.67	.62	.67	.81	.67
27	.67	.67	.71	.67	.58	.67	.67	.67	.62	.67	.67	.67
28	.67	.67	.71	.67	.58	1.23	.67	.67	.96	1.23	.67	.67
29	.67	.....	.71	.67	.58	.91	.67	.67	.67	1.28	.67	.67
30	.62	.....	.67	.67	.58	.81	.67	.67	.67	.67	.67	.67
31	.62	.....	.67	.....	.58	.....	.67	.67	.....	.67	.....	.67

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Monthly discharge of Akulikuli Spring near Kealia, Kauai, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	3.39	0.62	0.78	74
February	2.21	.62	.83	71
March	2.36	.58	.70	67
April	1.52	.67	.72	66
May	1.52	.58	.78	74
June	4.22	.58	1.06	98
July	1.76	.67	.77	73
August	.81	.67	.68	65
September	1.64	.62	.72	66
October	1.28	.58	.70	67
November	2.43	.67	.80	74
December	1.95	.67	.84	80
The year	4.22	.58	.78	875

KAPAHI DITCH AT KAPAHI, NEAR KEALIA, KAUAI.

Location.—About 4 miles west of Kealia and 500 feet below diversion dam on Kapaa River.

Records available.—April 15, 1909, to December 31, 1913.

Gage.—Watson water-stage recorder.

Discharge measurements.—There is a 20-foot sharp-crested weir immediately below the gage, but current-meter measurements give a different rating from the weir formula, and the meter rating is used.

Diversion.—Ditch diverts part of flow of Kapaa River.

Accuracy.—Records good.

Cooperation.—Station is maintained in cooperation with the Makee Sugar Co.

Daily discharge, in second-feet, of Kapahi ditch at Kapahi, near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	16.9	10.6	11.2	14.2	10.0	14.8	26.0	14.2	20.0	11.8	12.4	36.0
2	27.0	10.6	10.6	17.6	22.4	23.2	71.0	14.2	18.4	11.2	18.4	24.0
3	14.8	10.6	10.0	15.5	14.8	93.0	29.0	12.4	16.2	10.6	22.4	10.6
4	13.0	10.6	9.0	13.6	14.8	6.0	31.0	11.8	21.6	10.0	16.2	9.5
5	12.4	10.6	9.5	14.2	13.0	10.0	27.0	11.2	33.5	10.0	15.5	7.5
6	14.2	138	10.0	13.0	45.0	12.4	20.0	11.8	27.0	17.6	14.2	7.5
7	19.2	60.0	18.4	12.4	36.0	12.4	16.9	17.6	18.4	24.0	24.0	20.8
8	27.0	17.6	16.9	11.8	43.5	18.4	14.8	14.2	15.5	31.0	20.8	36.0
9	20.0	16.2	13.0	22.4	30.0	17.6	16.2	18.4	13.6	33.5	17.6	27.0
10	20.0	14.8	10.6	16.2	18.4	14.2	13.6	14.2	12.4	35.0	16.2	22.4
11	24.0	16.2	9.5	20.0	38.5	17.6	13.6	13.0	12.4	19.2	24.0	20.0
12	46.5	13.0	9.5	14.2	18.4	20.0	16.2	16.9	14.2	16.9	20.8	18.4
13	72.0	10.6	10.0	42.5	5.0	23.2	37.5	22.4	11.8	21.6	20.8	17.6
14	32.5	10.6	10.0	60.0	3.5	23.2	28.0	16.9	12.4	18.4	21.6	16.9
15	31.0	13.0	9.5	59.0	3.5	21.6	17.6	15.5	12.4	20.8	18.4	16.2
16	51.0	14.2	11.8	21.6	5.5	26.0	16.9	14.8	11.8	16.2	14.8	14.8
17	24.0	11.8	11.2	42.5	7.0	18.4	14.8	13.6	11.2	14.8	18.4	14.8
18	16.9	66.0	10.6	45.0	7.0	16.9	13.6	13.0	11.2	22.4	18.4	16.2
19	14.8	43.5	10.0	27.0	11.2	15.5	26.0	14.2	11.2	16.2	19.2	14.8
20	14.2	26.0	13.0	17.6	12.4	14.2	20.8	13.6	11.2	13.0	11.8	14.2
21	54.0	20.0	17.6	16.2	12.4	14.2	15.5	32.5	10.6	38.5	14.2	14.8
22	26.0	18.4	25.0	16.2	13.6	13.6	13.6	17.6	12.4	82.0	14.8	14.2
23	17.6	48.0	74.0	17.6	13.0	13.6	12.4	30.0	11.8	31.0	14.2	13.6
24	29.0	36.0	60.0	13.6	16.9	13.0	15.5	17.6	11.2	20.0	13.6	13.6
25	25.0	15.5	7.0	20.0	16.2	13.0	21.6	38.5	10.6	18.4	12.4	13.0
26	17.6	13.6	7.5	14.2	13.6	19.2	23.2	23.2	10.6	16.2	13.0	13.0
27	15.5	12.4	6.5	12.4	13.6	45.0	24.0	43.5	10.6	13.6	32.5	13.0
28	14.2	11.8	7.0	11.8	15.5	31.0	16.2	16.9	40.0	43.5	53.0	13.0
29	13.0	.....	12.4	14.2	13.6	25.0	36.0	14.8	12.4	23.2	16.2	13.0
30	12.4	.....	7.5	14.2	24.0	42.5	16.9	23.2	11.8	15.5	15.5	13.0
31	10.6	.....	13.6	.....	14.2	.....	15.5	27.0	.....	14.2	.....	13.0

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Monthly discharge of Kapahi ditch at Kapahi, near Kealia, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	72.0	10.6	24.1	1,480	A.
February	138	10.6	25.0	1,390	A.
March	74.0	6.5	14.9	916	A.
April	60.0	11.8	21.7	1,290	A.
May	45.0	3.5	17.0	1,050	A.
June	93.0	6.0	21.6	1,290	A.
July	71.0	12.4	22.0	1,350	A.
August	43.5	11.2	18.7	1,150	A.
September	40.0	10.6	15.3	910	A.
October	82.0	10.0	22.3	1,370	A.
November	53.0	11.8	18.8	1,120	A.
December	36.0	7.5	16.5	1,010	A.
The year	138	3.5	19.8	14,300	

KANEHA DITCH NEAR KEALIA, KAUAI.

Location.—About 5 miles northwest of Kealia, a short distance below the outlet from the Kaneha reservoir.

Records available.—January 1, 1909, to December 31, 1913.

Gage.—Staff.

Discharge measurements.—Made with a 20-foot sharp-crested weir.

Accuracy.—Records poor.

Cooperation.—Station is maintained in cooperation with the Makee Sugar Co.

Daily discharge, in second-feet, of Kaneha ditch near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		1.9				4.8	5.6	5.2	20	3.6	6.0	5.6
2		1.9				2.2	5.2	6.8	10	3.2	5.6	5.6
3		2.2				12	5.2	7.8	8.8	3.2	12	6.8
4		16				35	5.6	7.3	13		8.3	10
5	3.6					26	6.4	6.8	22		6.4	7.3
6	4.0					8.3	6.0	6.8	13		4.8	8.3
7						8.8	5.6	6.8	9.0		4.4	7.8
8						7.8	4.8	8.3	7.3		5.2	8.8
9						10	4.8	11	6.4		4.0	7.3
10						11	3.2	7.8	6.0		3.6	6.4
11						11	2.8	6.0	5.6	6.4	5.2	6.0
12	11					6.4	3.6	5.6	6.0	4.4	3.2	6.0
13	6.8					6.0	11	4.8	6.4	3.6	1.6	6.0
14	12					6.0	9.5	6.0	6.0	12	7.8	6.4
15	6.8					6.0	7.3	5.6	6.4	22	6.0	6.0
16	5.2					6.8	7.3	6.0	6.8	21	6.4	4.8
17					13	6.0	8.8	5.6	3.2	12	6.4	4.4
18	4.4				11	5.6	8.6	4.8	2.8	7.3	6.0	4.4
19	4.4				7.8	5.2	8.3	6.4	3.2	5.2	8.3	4.4
20	4.4				5.2	4.8	6.8	7.3	3.2	6.4	6.4	3.6
21	8.3				4.4	4.4	6.0	7.3	10	7.8	6.0	3.2
22					3.6	2.2	4.8	6.4	4.0	7.3	5.6	3.2
23		5.2			3.2	4.0	6.0	5.2	3.6	9.0	6.0	3.2
24		4.0			3.2	2.2	6.0	6.0	4.8	10	7.3	4.4
25	4.4	3.6			2.8	1.6	5.6	7.8	5.2	7.8	5.2	4.8
26	4.4	3.6			2.5	1.6	9.5	7.3	4.0	13	3.2	5.2
27		3.6			2.5	11	10	7.8	3.2	14	1.9	4.8
28					2.5	6.4	8.3	10	4.4		1.6	3.6
29					3.2	5.6	9.5	9.0	4.0		20	2.5
30					4.0	6.8	7.3	13	3.6		15	2.5
31					5.2		5.2	8.8				2.5

NOTE.—No record Jan. 1–4, 7–11, 17, 22–24, 27–31; Feb. 5–22; Feb. 28–May 16; Oct. 4–10, 28–31. Discharge interpolated May 18–20 and July 18.

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Monthly discharge of Kaneha ditch near Kealia, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 5-6, 12-16, 18-21, 25-26	12	3.6	6.13	158	C.
February 1-4, 23-27	16	1.9	4.67	83	C.
May 17-31	13	2.5	4.94	147	C.
June	35	1.6	7.85	467	C.
July	11	2.8	6.60	406	C.
August	13	4.8	7.14	439	C.
September	22	2.8	7.06	420	C.
October 1-3, 11-27	22	3.2	8.96	355	C.
November	20	1.6	6.31	375	C.
December	10	2.5	5.35	329	C.
The period				3,180	

ANAHOLA RIVER ABOVE DAM AT KIOKALA, NEAR KEALIA, KAUAI.

Location.—About one-fourth mile above dam at Kiokala and 6 miles northwest of Kealia.

Records available.—August 22 to November 2, 1910; December 28, 1912, to December 31, 1913. December 15, 1910, to December 28, 1912, at dam at Kiokala.

Drainage area.—5.3 square miles.

Gage.—Friez water-stage recorder August 22 to November 2, 1910, and December 28, 1912, to December 31, 1913. From December 15, 1910, to December 28, 1912, an inclined staff gage.

Control.—Permanent.

Discharge measurements.—Made by wading and from foot bridge.

Accuracy.—Records good for January and from May to August; for other months fair.

Cooperation.—Station maintained in cooperation with the Makee Sugar Co.

The following discharge measurement was made by W. V. Hardy:

May 19, 1913: Gage height, 1.24 feet; discharge, 24.5 second-feet.

Daily discharge, in second-feet, of Anahola River above dam at Kiokala, near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	19	10	13	20	9.6	13	17	12	17	12	10	37
2	56	9.5	13	16	17	17	33	12	20	13	30	30
3	19	9.2	12	16	11	97	18	11	51	10	15	211
4	15	9.3	11	16	9.6	62	21	11	17	9.6	13	174
5	20	10	11	13	9.6	30	22	10	17	9.6	11	87
6	16	142	11	12	34	23	13	10	44	11	11	93
7	15	53	12	12	26	21	12	11	22	17	57	75
8	21	21	25	11	35	20	12	12	15	23	23	53
9	15	16	17	15	22	24	12	17	13	28	35	37
10	13	17	11	13	15	26	11	12	13	15	24	30
11	21	17	11	13	67	29	10	10	12	13	32	26
12	36	13	10	14	74	20	11	13	12	13	26	22
13	61	12	10	46	35	23	26	13	12	20	26	22
14	30	11	10	61	45	18	20	13	13	17	17	.....
15	28	12	10	48	29	17	13	15	18	20	15	.....
16	30	15	13	22	41	20	12	24	13	17	15	.....
17	19	11	10	36	41	18	11	15	12	13	16	.....
18	17	63	10	34	40	17	11	14	12	13	16	.....
19	15	52	10	27	26	15	14	12	14	11	46	.....
20	16	33	11	16	22	14	16	11	13	10	137	.....
21	28	23	17	15	20	13	12	16	13	12	176	.....
22	36	22	20	18	18	13	11	12	13	49	61	.....
23	16	34	127	18	17	13	11	11	12	57	52	.....
24	15	25	135	13	18	13	14	13	12	22	57	.....
25	19	20	136	14	18	13	30	22	11	17	89	.....
26	15	17	67	11	17	13	18	13	11	15	73	.....
27	15	15	39	9.9	16	28	31	17	11	13	49	.....
28	13	15	33	10	15	19	15	17	23	28	43	.....
29	12	.....	27	9.6	15	15	18	19	11	14	49	.....
30	12	.....	21	9.6	15	18	15	15	10	12	55	.....
31	11	.....	19	.....	14	.....	13	21	.....	12	.....	.....

NOTE.—No record Dec. 14-31. Discharge interpolated Mar. 28-29 and Nov. 29.

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Monthly discharge of Anahola River above dam, at Kiokala, near Kealia, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	61	11	21.7	1,330	A.
February	142	9.2	25.2	1,400	B.
March	136	10	28.5	1,750	B.
April	61	9.6	19.6	1,170	B.
May	74	9.6	25.5	1,570	A.
June	97	13	22.7	1,350	A.
July	33	10	16.2	996	A.
August	24	10	14.0	861	A.
September	51	10	16.2	964	B.
October	57	9.6	17.6	1,080	B.
November	176	10	42.6	2,530	B.
December 1-13	211	22	69.0	1,780	B.
The period	.....	.....	.....	16,800	

ANAHOLA DITCH AT KIOKALA, NEAR KEALIA, KAUAI.

Location.—About 6 miles northwest of Kealia.

Records available.—May 10, 1909, to December 31, 1913.

Gage.—Watson water-stage recorder.

Discharge measurements.—Made with 10-foot sharp-crested weir.

Accuracy.—Records good.

Cooperation.—Station maintained in cooperation with the Makee Sugar Co.

Daily discharge, in second-feet, of Anahola ditch at Kiokala, near Kealia, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	12.1	6.6	9.4	13.2	8.7	9.4	11.1	7.8	11.1	5.7	4.4	.....
2	13.6	6.3	8.7	12.5	11.8	9.4	12.5	7.8	10.1	6.6	7.8	.....
3	13.2	6.0	8.1	12.5	9.7	14.7	11.8	6.9	17.1	4.2	9.0	.....
4	11.8	6.0	7.8	12.1	8.7	13.6	11.8	6.6	17.2	3.4	7.5	.....
5	11.8	7.5	7.2	11.8	8.1	12.5	12.1	6.0	17.4	3.4	6.6	.....
6	12.1	15.9	8.1	11.1	11.8	11.8	10.4	5.5	17.5	4.7	5.7	.....
7	10.7	15.1	8.4	10.4	13.2	11.4	10.1	5.7	14.0	8.4	9.7	.....
8	12.8	12.8	10.7	10.1	14.0	11.1	9.4	7.2	10.7	12.1	10.1	.....
9	11.8	12.1	11.1	11.8	12.8	11.4	9.7	11.1	9.0	12.1	10.7	.....
10	11.8	11.4	7.8	10.7	12.1	11.8	8.4	7.8	7.8	8.7	10.1	.....
11	10.4	12.5	6.9	11.4	12.5	11.8	7.5	6.0	7.2	6.3	10.4	.....
12	13.2	10.1	6.3	10.1	16.7	11.1	7.5	7.8	6.0	6.3	10.1	.....
13	14.3	8.7	6.3	14.0	8.1	10.7	11.8	9.7	6.0	9.7	10.1	.....
14	12.8	11.4	6.0	14.7	.....	10.7	12.1	8.4	7.5	8.7	9.0	.....
15	12.5	9.0	6.0	15.1	.....	10.7	9.7	10.4	11.1	10.4	8.4	.....
16	13.2	10.4	8.4	13.2	.....	11.1	8.1	12.1	7.2	9.4	8.1	.....
17	11.4	8.4	6.3	13.6	4.2	10.7	7.2	10.4	6.0	6.3	8.7	.....
18	10.1	14.3	6.0	14.0	10.4	10.7	7.2	9.4	5.7	5.2	8.4	.....
19	9.4	12.5	5.5	13.2	10.1	10.4	8.7	6.9	6.9	4.7	10.1	.....
20	10.1	13.6	6.9	12.1	9.7	9.7	10.7	5.5	5.7	4.2	13.2	.....
21	11.4	12.5	10.7	12.1	9.7	9.0	7.8	8.7	6.3	6.0	.....	.....
22	14.0	12.5	11.4	12.5	9.7	9.0	6.9	6.0	5.7	9.7	.....	.....
23	11.8	13.2	6.0	12.1	9.4	8.7	6.9	5.2	5.5	14.7	.....	.....
24	10.7	12.8	.4	11.1	9.4	8.4	7.8	6.3	4.7	13.2	.....	.....
25	11.1	12.1	.1	11.1	9.4	8.7	14.0	12.5	4.4	11.8	.....	.....
26	11.1	11.4	.....	10.7	9.4	8.7	12.8	8.1	3.9	9.4	.....	.....
27	10.7	10.7	.....	9.4	9.0	10.1	14.3	9.0	4.2	7.2	.....	.....
28	8.7	9.7	.....	9.7	9.0	11.1	10.7	10.7	9.7	11.8	.....	.....
29	7.8	.....	5.5	9.4	8.7	10.4	12.5	12.1	5.7	8.1	.....	.....
30	7.5	.....	13.6	9.0	9.0	11.1	10.7	9.4	4.4	6.0	.....	.....
31	7.2	.....	13.2	.....	8.7	.....	9.4	11.8	.....	5.2	.....	.....

NOTE.—No record Mar. 26-28, May 14-16, and Nov. 21 to Dec. 31. Discharge Sept. 4 and 5 interpolated.

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Monthly discharge of Anahola ditch at Kiokala, near Kealia, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	14.3	7.2	11.7	719	A.
February	15.9	6.0	10.9	605	A.
March	13.6	.1	7.60	422	A.
April	15.1	9.0	11.8	702	A.
May	16.7	4.2	10.1	563	A.
June	14.7	8.4	10.7	637	A.
July	14.3	6.9	10.1	621	A.
August	12.5	5.2	8.35	513	A.
September	17.5	3.9	8.52	507	A.
October	14.7	3.4	7.86	483	A.
November 1-20	13.2	4.4	8.90	353	A.
The period				6,120	

KALIHIWAI RIVER NEAR KILAUEA, KAUAI.

Location.—One-half mile below Hoopouli Falls, about 2 miles west of Kilauea, and about 5 miles above mouth of river. Reached by saddle horse on trail from Princeville ranch.

Records available.—August 21, 1912, to December 31, 1913.

Drainage area.—3.9 square miles.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Accuracy.—Records fair except for November and December, 1913, when they were poor.

Cooperation.—Station is maintained in cooperation with the Princeville ranch.

Discharge measurements of Kalihiwai River near Kilauea, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec. ft.*			*Feet.*	*Sec. ft.*
Apr. 18	D. E. Horner	6.76	114	Apr. 20	D. E. Horner	6.44	46.8
Apr. 19	do	6.62	76.8	May 23	W. V. Hardy	6.08	24.1

Daily discharge, in second-feet, of Kalihiwai River near Kilauea, Kauai, for 1912-13.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.						1912.					
1		29	24	25	28	16		25	25	24	36
2		32	24	24	36	17		25	24	24	39
3		29	23	24	76	18		25	24	29	44
4		29	22	24	2,500	19		58	29	25	41
5		29	22	25	224	20		58	46	111	36
6		46	23	32	76	21	29	24	76	29	36
7		32	24	24	46	22	124	23	25	28	36
8		29	98	24	46	23	36	23	29	25	52
9		29	36	32	41	24	29	24	36	27	46
10		29	25	24	41	25	29	22	32	25	46
11		29	24	24	38	26	29	22	34	25	44
12		29	24	24	36	27	98	22	32	24	41
13		27	24	24	36	28	36	22	29	27	36
14		25	24	24	46	29	41	22	28	29	35
15		25	23	25	41	30	36	23	27	25	34
						31	32		26		29

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Daily discharge, in second-feet, of Kalihiwai River near Kilauea, Kauai, for 1912–13—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	29	24	24	36	41	18	41	25	36	22	25	400
2	29	23	24	36	87	18	36	24	1,050	21	25	264
3	28	23	24	36	63	98	52	24	46	21	25	1,450
4	27	24	23	36	38	46	41	23	38	21	24	224
5	29	24	23	27	25	29	35	23	32	21	25	154
6	36	750	23	26	264	25	35	23	30	21	26	187
7	36	98	24	25	46	25	32	23	30	37	31	180
8	41	36	25	24	62	26	32	22	29	32	32	174
9	36	29	23	32	41	32	31	24	32	31	37	50
10	48	24	22	29	36	30	30	24	30	29	39	46
11	46	24	22	32	50	29	29	24	29	27	50	41
12	187	23	22	32	80	29	29	41	27	25	400	39
13	98	23	22	34	36	27	48	48	26	25	500	36
14	58	22	22	67	32	32	46	41	25	25	187	34
15	52	23	22	62	46	36	38	36	25	24	154	31
16	46	24	23	54	62	36	38	27	24	24	111	29
17	41	24	23	111	80	36	36	26	32	24	76	29
18	38	214	24	119	38	32	29	24	32	24	62	29
19	98	154	23	85	29	30	27	23	24	23	700	28
20	98	46	23	52	29	29	26	23	32	36	1,100	28
21	111	29	25	38	26	27	25	24	24	32	550	28
22	98	29	32	38	25	27	32	24	24	29	650	27
23	76	29	348	46	25	25	24	24	23	72	400	24
24	58	29	390	41	24	24	24	24	23	58	308	24
25	41	24	400	80	23	24	52	24	23	36	600	24
26	32	27	308	63	22	23	41	24	23	29	187	24
27	29	25	76	46	21	244	32	24	22	24	154	23
28	25	111	58	41	21	41	29	27	22	28	124	23
29	24	.....	41	41	20	52	27	48	22	27	2,050	22
30	24	.....	41	39	19	41	26	39	22	27	600	22
31	24	.....	38	.....	18	.....	25	35	.....	26	.....	22

Monthly discharge of Kalihiwai River near Kilauea, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
August 21-31	124	29	47.2	1,030	B.
September	58	22	28.9	1,720	B.
October	98	22	31.0	1,910	B.
November	111	24	28.5	1,700	B.
December	2,500	28	127	7,810	B.
1913.					
January	187	24	53.0	3,260	A.
February	750	22	70.2	3,900	A.
March	400	22	71.5	4,400	A.
April	119	24	47.6	2,830	A.
May	264	18	46.1	2,830	A.
June	244	18	39.7	2,360	A.
July	52	24	33.8	2,080	B.
August	48	22	27.9	1,720	B.
September	1,050	22	61.9	3,680	B.
October	72	21	29.1	1,790	B.
November	2,050	24	308	18,300	C.
December	1,450	22	120	7,380	C.
The year	2,050	18	75.4	54,500	

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HANALEI RIVER NEAR HANALEI, KAUAI.

Location.—About 5 miles up the river from Hanalei.
Records available.—December 28, 1911, to December 31, 1913.
Drainage area.—19.2 square miles.
Gage.—Staff.
Control.—Probably permanent.
Discharge measurements.—Cable and car or by wading.
Accuracy.—Records good for January, February, April, May, August, September, and October; for other months fair.

Discharge measurements of Hanalei River near Hanalei, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Mar. 25	Hardy and Horner	7.90	1,160	Nov. 12	W. V. Hardy	8.50	1,620
28	W. V. Hardy	6.75	214				

Daily discharge, in second-feet, of Hanalei River near Hanalei, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	124	124	93	93	93	93	124	93	158	124	93	124
2	158	124	93	93	158	93	1,180	93	248	93	248	124
3	158	124	93	124	93	825	364	93	158	93	158	825
4	124	124	93	124	93	124	364	93	124	93	124	124
5	124	158	93	93	124	124	364	93	124	93	93	124
6	124	200	93	93	124	124	124	124	124	93	93	124
7	124	124	124	93	200	124	124	124	158	248	200	124
8	124	124	124	124	124	124	124	124	124	200	158	124
9	124	124	93	124	124	158	124	124	124	124	158	93
10	158	124	93	124	124	124	124	93	93	93	500	93
11	124	124	93	124	124	124	124	93	93	93	364	93
12	158	124	93	93	200	124	124	124	124	93	955	93
13	302	93	93	158	124	158	248	158	124	124	200	93
14	158	93	93	124	124	124	200	158	124	124	158	93
15	158	93	93	124	124	124	158	124	93	124	124	93
16	124	93	93	93	124	364	124	248	93	93	124	93
17	124	124	93	93	124	124	124	158	93	93	124	93
18	124	291	93	93	124	124	158	124	93	124	158	93
19	124	158	124	93	124	93	124	93	124	93	248	93
20	158	124	124	93	124	93	93	93	93	93	910	93
21	124	124	124	93	124	124	93	124	93	93	200	93
22	124	124	124	93	124	124	93	124	93	93	158	93
23	124	93	124	93	124	124	124	93	93	93	158	93
24	124	124	910	93	124	124	124	124	93	93	158	93
25	124	124	910	124	93	124	124	124	68	124	200	93
26	124	93	655	93	93	124	93	115	68	124	200	93
27	124	93	124	124	93	364	158	124	68	124	124	93
28	124	93	224	124	93	124	124	364	158	124	93	93
29	124	.....	93	124	124	124	93	158	124	93	93	93
30	124	.....	124	158	124	124	93	248	124	93	158	93
31	124	.....	124	.....	93	.....	93	200	.....	124	.....	124

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Monthly discharge of Hanalei River near Hanalei, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	302	124	137	8,420	A.
February	291	93	126	7,000	A.
March	910	93	178	10,900	B.
April	158	93	110	6,550	A.
May	200	93	122	7,500	A.
June	825	93	162	9,640	B.
July	1,180	93	184	11,300	B.
August	364	93	136	8,360	A.
September	248	68	116	6,900	A.
October	248	93	112	6,890	A.
November	955	93	224	13,300	B.
December	825	93	125	7,690	B.
The year	1,180	68	144	104,000	

KUNA DITCH NEAR HANALEI, KAUAI.

Location.—About 4 miles up the river from Hanalei and 500 feet below diversion from Hanalei River.

Records available.—January 17, 1912, to September 30, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made from footbridge.

Accuracy.—Records fair.

Discharge measurements of Kuna ditch near Hanalei, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Mar. 26	W. V. Hardy	4.88	23.8
Aug. 26	do	4.64	19.4

Daily discharge, in second-feet, of Kuna ditch near Hanalei, Kauai, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	5.0	4.5	22	22	22	27	34	22	25
2	5.7	4.5	22	22	24	26	48	22	29
3	5.7	4.5	22	24	22	29	38	22	25
4	5.7	4.5	22	24	22	28	38	22	24
5	5.0	5.7	22	22	22	28	38	23	24
6	5.0	7.4	22	22	22	28	35	23	24
7	5.0	4.5	24	22	24	27	35	23	25
8	4.5	4.5	24	24	22	27	35	23	24
9	4.5	4.5	22	24	22	28	35	23	24
10	5.0	4.5	22	24	22	28	34	22	23
11	4.5	4.5	22	24	22	28	34	22	24
12	5.0	4.5	22	22	24	27	34	23	24
13	6.5	22	22	26	22	28	35	24	24
14	5.0	22	22	24	22	28	34	24	13
15	5.0	22	22	24	22	28	32	23	13
16	5.0	22	22	22	22	31	32	27	13
17	5.0	24	22	22	22	28	34	23	13
18	5.0	24	22	22	22	28	36	24	13
19	5.0	24	24	22	22	28	35	23	13
20	5.7	24	24	22	22	28	31	22	13
21	5.0	24	24	22	22	28	31	23	13
22	5.0	24	24	22	22	30	31	23	13
23	5.0	22	24	22	22	30	32	22	13
24	5.0	24	42	22	22	30	32	23	11
25	5.0	24	30	22	21	30	34	24	11
26	5.0	22	26	22	21	30	32	21	11
27	5.0	22	24	22	28	38	32	24	13
28	5.0	22	22	22	29	32	26	29	14
29	5.0	.....	22	22	28	32	22	25	13
30	4.5	.....	24	24	28	32	22	27	13
31	4.5	.....	24	.....	28	.....	22	26	.....

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Monthly discharge of Kuna ditch near Hanalei, Kauai, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	6.5	4.5	5.06	311	C.
February	24	4.5	15.2	844	C.
March	42	22	23.7	1,460	B.
April	26	22	22.7	1,350	B.
May	29	21	23.1	1,420	B.
June	38	26	29.0	1,730	B.
July	48	22	33.0	2,030	B.
August	29	22	23.5	1,440	B.
September	29	11	18.2	1,080	B.
The period				11,600	

WAINIHA RIVER (EAST AND WEST CHANNELS) AT POWER HOUSE, NEAR WAINIHA, KAUAI.

Location.—About 2 miles south of Wainiha and just northeast of Kauai Electric Co.'s power house.

Records available.—East Channel, February 25, 1912, to December 31, 1913; West Channel, December 30, 1911, to December 31, 1913.

Drainage area.—14.7 square miles.

Gage.—Two inclined timber gages—one on each channel—to obtain the total flow of the river at this point.

Control.—Two large channels, both rocky and probably permanent. The natives build fish dams at the point where the river divides above the stations, and this shifts the water from one channel to the other.

Discharge measurements.—Made from wire suspension footbridge over each channel, or by wading.

Accuracy.—East Channel, records fair; West Channel, records good.

Cooperation.—Stations maintained in cooperation with the Kauai Electric Co.

Discharge measurements of east channel of Wainiha River near Wainiha, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Mar. 31	W. V. Hardy	6.73	10.3	Nov. 13	W. V. Hardy	9.30	407
Apr. 24	D. E. Horner	6.72	12.7	Nov. 14	do	8.10	106
Aug. 23	W. V. Hardy	6.59	5.9				

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Daily discharge, in second-feet, of east channel of Wainiha River near Wainiha, Kauai, for 1912–13.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.												
1	.....	.....	94	28	8	14	12	7	46	16	14	135
2	.....	.....	74	18	10	14	10	7	40	14	7	732
3	.....	.....	94	12	16	14	10	5	34	40	10	1,320
4	.....	.....	57	31	18	18	10	6	18	8	8	149
5	.....	.....	66	31	26	14	16	14	12	14	8	34
6	.....	.....	70	94	23	14	20	20	242	12	7	26
7	.....	.....	50	256	28	14	37	26	43	12	10	16
8	.....	.....	70	366	34	14	12	34	18	15	79	29
9	.....	.....	134	242	14	18	27	28	18	16	141	20
10	.....	.....	256	74	10	14	115	8	10	23	18	10
11	.....	.....	642	57	10	14	126	14	10	10	12	8
12	.....	.....	185	66	10	14	46	12	9	10	7	7
13	.....	.....	106	43	14	18	217	20	5	14	7	10
14	.....	.....	74	34	119	14	57	230	3	14	7	8
15	.....	.....	46	37	74	16	40	34	5	10	16	10
16	.....	.....	34	20	28	18	17	14	5	16	12	16
17	.....	.....	20	43	26	14	108	8	10	35	10	10
18	.....	.....	14	23	20	18	15	7	7	26	12	10
19	.....	.....	4	8	14	20	12	7	5	45	26	12
20	.....	.....	28	4	14	23	12	7	5	46	16	26
21	.....	.....	23	5	16	23	16	18	6	106	141	20
22	.....	.....	10	7	31	16	12	26	16	40	149	26
23	.....	.....	6	8	18	16	12	16	8	28	100	70
24	.....	.....	28	10	23	20	16	14	8	14	20	175
25	.....	10	349	12	16	14	10	9	6	16	12	134
26	.....	7	37	14	14	14	20	10	5	217	10	100
27	.....	14	23	8	23	14	12	79	5	34	8	18
28	.....	12	34	7	256	10	7	66	8	34	10	16
29	.....	16	18	8	89	10	8	66	10	18	119	10
30	.....	.....	16	5	28	10	12	119	10	23	141	10
31	.....	.....	16	.....	18	.....	10	94	.....	31	.....	10
1913.												
1	10	6	7	50	7	5	18	7	84	7	18	61
2	37	6	7	40	157	5	157	7	31	7	29	53
3	20	5	7	23	37	34	57	5	18	7	40	464
4	14	6	7	14	43	12	66	5	12	6	40	149
5	10	8	7	10	70	12	61	5	12	6	16	134
6	10	7	7	10	89	19	23	5	14	10	12	126
7	8	20	12	10	43	14	26	8	10	31	94	126
8	84	7	8	10	34	7	18	16	7	242	28	112
9	16	6	7	18	12	14	11	23	8	23	141	89
10	34	5	7	18	8	94	10	7	7	10	61	53
11	28	5	7	70	5	53	7	7	7	10	868	57
12	20	5	7	53	50	18	8	20	10	10	868	50
13	50	5	7	84	53	26	50	20	7	61	485	43
14	37	5	7	79	28	23	70	50	7	18	106	43
15	37	5	7	206	12	18	20	20	7	10	126	43
16	112	5	7	46	10	26	16	50	7	18	126	43
17	12	10	37	100	46	8	14	18	7	7	149	40
18	10	34	10	46	40	9	10	10	7	7	66	37
19	8	34	16	66	12	12	14	10	10	7	2,250	37
20	10	20	18	37	10	10	14	10	7	7	332	34
21	10	16	16	18	8	12	8	10	7	8	100	35
22	10	7	18	7	5	10	7	8	8	7	270	35
23	8	7	79	8	7	7	7	7	7	7	185	37
24	7	26	70	14	8	7	14	8	7	8	217	37
25	7	26	89	66	10	18	23	20	7	7	485	34
26	7	9	175	12	10	40	23	10	7	7	230	34
27	8	8	50	18	8	46	14	10	6	7	53	34
28	7	7	37	31	7	31	14	12	18	7	70	34
29	6	.....	34	53	6	14	26	66	7	7	620	34
30	6	.....	10	57	18	18	7	50	7	7	79	34
31	10	.....	10	.....	6	.....	8	23	.....	7	.....	34

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Monthly discharge of east channel of Wainiha River near Wainiha, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
February 25–29	16	7	11.8	117	
March	642	6	86.4	5,310	C.
April	366	4	52.4	3,120	C.
May	256	8	33.8	2,080	C.
June	23	10	15.5	922	C.
July	217	7	34.6	2,130	B.
August	230	5	33.1	2,040	B.
September	242	3	20.9	1,240	C.
October	217	8	30.9	1,900	A.
November	149	7	37.9	2,260	B.
December	1,320	7	104	6,400	B.
The period				27,500	
1913.					
January	112	6	21.1	1,300	A.
February	34	5	11.1	616	A.
March	175	7	25.4	1,560	A.
April	206	7	42.5	2,530	A.
May	157	5	27.7	1,700	A.
June	94	5	20.7	1,230	A.
July	157	7	26.5	1,630	A.
August	66	5	17.0	1,050	A.
September	84	6	12.0	714	B.
October	242	6	18.8	1,160	B.
November	2,250	12	272	16,200	C.
December	464	34	70.2	4,320	C.
The year	2,250	5	46.9	34,000	

Discharge measurements of west channel of Wainiha River near Wainiha, Kauai, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Aug. 23	W. V. Hardy	5.50	112	Nov. 13	W. V. Hardy	5.87	242
Nov 13	do	6.19	386				

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Daily discharge, in second-feet, of west channel of Wainiha River near Wainiha, Kauai, for 1912–13.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.												
1	90	102	390	272	140	140	128	115	340	135	158	115
2	115	192	272	210	140	128	115	115	318	128	128	820
3	140	210	365	158	147	115	115	115	272	295	140	1,310
4	115	192	250	250	158	140	115	90	210	115	128	440
5	140	140	250	295	192	128	140	175	158	158	115	250
6	115	115	365	440	140	115	175	192	580	147	115	272
7	115	115	250	580	140	115	210	210	272	128	128	192
8	175	128	295	670	175	115	158	272	210	140	272	210
9	140	140	465	640	140	140	175	250	175	168	440	210
10	128	140	700	365	115	115	365	140	128	175	230	140
11	90	158	790	250	115	115	318	158	115	115	158	140
12	115	128	440	295	115	115	175	128	115	128	115	128
13	175	128	295	760	230	140	365	175	102	128	115	140
14	140	128	250	250	415	115	272	520	90	128	115	140
15	115	128	192	272	295	128	230	295	115	115	230	140
16	90	115	192	230	158	128	175	175	115	140	175	192
17	90	115	192	390	158	115	318	128	140	230	140	140
18	90	158	158	272	128	175	158	115	115	175	192	140
19	90	140	128	158	140	192	140	115	115	340	272	208
20	90	158	272	158	140	175	128	115	115	365	192	390
21	90	272	295	128	158	158	140	175	115	465	415	210
22	90	340	192	128	192	128	140	210	175	272	415	272
23	102	390	158	128	158	158	140	175	120	210	250	465
24	175	340	250	140	192	175	158	158	102	158	670	440
25	128	250	580	158	158	128	140	175	102	175	158	318
26	102	230	272	192	140	115	192	140	90	490	140	230
27	140	272	210	250	210	135	140	440	90	230	115	147
28	115	192	250	175	440	115	115	250	140	272	115	140
29	115	210	210	192	295	115	128	192	140	175	318	140
30	128	.....	210	158	140	115	128	490	115	175	390	140
31	140	.....	230	.....	140	.....	115	295	.....	230	.....	140
1913.												
1	140	115	115	272	128	115	158	115	365	115	160	140
2	295	115	115	230	318	115	415	115	230	115	205	140
3	210	115	115	210	210	230	295	115	175	115	250	520
4	175	115	115	175	115	140	318	115	140	102	250	295
5	140	140	115	140	192	140	295	102	140	102	158	272
6	140	128	115	120	365	182	210	102	175	140	128	250
7	128	175	140	115	230	175	210	128	140	230	295	250
8	415	140	128	115	210	115	175	175	115	580	230	230
9	192	115	115	192	140	175	140	192	128	250	415	175
10	340	115	115	175	115	318	128	115	115	140	318	140
11	295	115	115	295	102	272	115	115	115	140	730	140
12	295	115	115	272	272	175	128	175	140	140	730	115
13	465	102	115	520	230	192	295	192	115	295	670	115
14	272	102	115	490	140	210	340	272	115	175	230	115
15	340	115	115	490	115	175	192	192	115	140	250	115
16	210	115	115	340	128	210	158	295	115	175	250	115
17	158	140	230	465	175	115	140	175	115	115	272	115
18	140	295	135	230	230	115	128	140	115	115	230	115
19	135	295	158	192	158	140	140	120	140	115	580	115
20	140	230	175	158	115	115	140	128	115	115	440	110
21	140	192	158	158	128	128	128	140	115	128	210	115
22	140	140	175	135	115	115	115	128	128	115	415	105
23	128	140	580	102	128	115	115	115	115	115	440	105
24	115	272	640	128	140	115	140	128	115	128	440	102
25	115	192	730	365	128	175	192	192	115	115	550	90
26	115	135	390	140	128	250	192	140	110	115	365	90
27	128	128	272	175	128	250	158	140	102	115	210	90
28	115	115	230	210	115	210	140	158	175	110	175	95
29	115	.....	210	192	115	140	210	318	115	115	490	102
30	115	.....	175	250	175	158	115	272	115	115	175	102
31	158	.....	175	.....	115	.....	115	210	.....	115	.....	102

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Monthly discharge of west channel of Wainiha River at power house, near Wainiha, Kauai, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
January	175	90	119	7,320	A.
February	390	102	184	10,600	A.
March	790	128	302	18,600	A.
April	760	128	285	17,000	A.
May	440	115	181	11,100	A.
June	192	115	133	7,910	A.
July	365	115	178	10,900	A.
August	520	90	203	12,500	A.
September	580	90	166	9,880	A.
October	490	115	203	12,500	A.
November	670	115	218	13,000	A.
December	1,310	115	269	16,500	A.
The year	1,310	90	204	148,000	
1913.					
January	465	115	194	11,900	A.
February	295	102	150	8,300	A.
March	730	115	204	12,500	A.
April	520	102	235	14,000	A.
May	365	102	165	10,100	A.
June	318	115	169	10,100	A.
July	365	115	185	11,400	A.
August	415	102	162	9,960	A.
September	365	102	138	8,210	A.
October	580	102	152	9,350	A.
November	730	128	342	20,400	A.
December	520	90	151	9,280	A.
The year	730	90	187	136,000	

MISCELLANEOUS MEASUREMENTS.

Measurements of streams on the island of Kauai at points other than regular gaging stations are listed below:

Miscellaneous discharge measurements on Kauai during the year ending Dec. 31, 1913.

Date.	Stream.	Tributary to—	Locality.	Gage height.	Discharge.
				Feet.	*Sec.ft.*
Feb. 9	Mohihi	Waimea River	Elevation about 3,500 feet	3.81	3.04
Mar. 5	....do	....do	....do	3.77	2.47
July 6	....do	....do	....do	3.92	4.70
Feb. 9	Waiakoali	....do	....do	2.52	3.03
Mar. 5	....do	....do	....do	2.50	2.74
July 8	....do	....do	....do	2.84	10.1
July 9	....do	....do	....do	2.57	3.53
Apr. 30	Kamenehune ditch [a]		Near Waimea	.60	1.60
July 28	....do		....do	.37	.62
Oct. 14	Hanapepe River	Waimea River	Near Eleele	.38	29.0
June 21	Hanapepe ditch [b]		....do	1.21	15.5
Do.	....do		....do	1.09	15.2
May 26	Kilauea River		Near Kilauea	7.70	4.69
Mar. 28	China ditch [c]		Near Hanalei	3.20	25.1
Apr. 26	....do		....do	3.35	26.5
May 25	....do		....do	3.64	30.5
Aug. 26	....do		....do		19.8
Mar. 22	Lumahai River		Near Wainiha		103
Mar. 30	....do		....do		131
Sept. 17	....do		....do		63.2
Oct. 21	....do		....do		55.2

[a] Diverts from Waimea River. [b] Diverts from Hanapepe River. [c] Diverts from Hanalei River.

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ISLAND OF OAHU.

KALIHI STREAM AT KIOI POOL, NEAR HONOLULU, OAHU.

Location.—At Kioi Pool, about three-eighths mile above Catholic Orphanage, 3 miles up Kalahi Road from King Street car line, and 5 miles north of Honolulu post office.

Records available.—September 8 to December 31, 1913.

Gage.—Gurley weight-driven register installed December 4. September 8 to November 22, 1913, Friez register. No record November 23 to December 3.

Control.—On November 20 a flood lowered the control 0.35 foot; after December 3, probably permanent.

Discharge measurements.—Made by wading or from suspension footbridge about 500 feet above station.

Discharge measurements of Kalihi Stream at Kioi Pool, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Sept. 8	G. R. White	2.64	2.37	Nov. 8	G. R. White	3.22	13.0
Sept. 27	do	2.58	1.71	Nov. 12	do	3.76	29.0
Oct. 4	do	2.58	1.29	Nov. 22	do	2.88	11.8
Oct. 12	do	2.54	1.06	Dec. 4	G K. Larrison	5.08	96.0
Oct. 25	do	2.53	.98	Dec. 11	J. C. Dort	2.95	11.0
Nov. 8	do	3.41	18.8	Dec. 23	do	2.50	5.26

Daily discharge, in second-feet, of Kalihi Stream at Kioi Pool, near Honolulu, Oahu, for 1913.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		1.6	0.8		16	2.2	1.7	4.4	6.9
2		1.6	3.1		17	1.9	1.4	4.4	7.3
3		1.6	1.4		18	2.6	1.3	5.0	6.6
4		1.6	1.0	78	19	2.8	1.2	13	6.5
5		1.7	1.0	46	20	2.2	1.1	28	6.3
6	2.9	1.9	1.0	76	21	2.2	1.1	18	6.0
7	2.6	2.4	8.6	64	22	4.4	1.1	9.8	5.7
8	2.5	3.8	18	28	23	2.1	1.1		28
9	2.4	1.8	12	20	24	3.1	1.1		5.1
10	2.5	1.7	8.4	16	25	2.2	1.0		5.0
11	2.2	1.5	16	13	26	1.9	1.0		4.9
12	1.9	1.3	18	10	27	1.6	1.0		4.6
13	2.2	1.6	12	9.6	28	1.6	1.0		4.5
14	3.1	2.1	6.8	10	29	1.6	.9		4.4
15	2.4	1.8	5.2	9.6	30	1.6	.9		4.2
					31		.8		4.2

NOTE.—Discharge estimated for days on which no gage heights were recorded, with the exception of period Nov. 23 to Dec. 3, 1913. Staff gage-height evidence indicated a maximum discharge of about 300 second-feet on night of Dec. 3.

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NUUANU STREAM AT LUAKAHA WEIR IN UPPER NUUANU VALLEY, NEAR HONOLULU, OAHU.

Location.—About 1 mile above reservoir No. 4 (main) in upper Nuuanu Valley, and about 5 miles from Honolulu post office.

Records available.— ———, 1903, to December 31, 1913.

Gage.—Head is measured on iron pipe set about 3.0 feet back from weir crest; read once daily.

Control.—Permanent.

Discharge measurements.—Made by 4-foot sharp-crested weir with end contractions; check measurements made with current meter by wading. At times floods exceed the capacity of the diversion channel and are not measured. Waste water from this station is measured by station on the Nuuanu Stream below reservoir No. 4.

Diversions.—Aqueduct diverts seepage from reservoir No. 4, including inflow from Nuuanu Valley drainage below reservoir No. 4.

Cooperation.—Records furnished by waterworks department of city of Honolulu.

Monthly discharge of Nuuanu Stream at Luakaha weir, in Nuuanu Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	11.8	2.76	4.62	284
February	4.71	2.41	2.60	144
March	9.18	1.47	3.07	189
April	9.53	2.41	3.69	220
May	15.0	2.41	4.96	305
June	15.2	3.63	4.77	284
July	5.14	2.88	3.79	233
August	4.85	2.64	2.94	181
September	4.16	1.47	2.24	133
October	2.19	.70	1.25	77
November	19.8	.56	5.60	333
December	20.2	6.04	9.56	588
The year	20.2	.56	4.10	2,970

NUUANU STREAM BELOW RESERVOIR NO. 2 WASTEWAY, NEAR HONOLULU, OAHU.

Location.—On Pali road in upper Nuuanu Valley, about 5 miles from Honolulu post office and 1 mile above end of car line.

Records available.—October 21 to December 31, 1913.

Gage.—Inclined staff read to hundredths.

Control.—Permanent.

Discharge measurements.—Low-water discharge measured by 2.0-foot sharp-crested weir with end contractions. Flood discharge measured by 12.0-foot sharp-crested weir with end contractions, which, with small weir, gives total flood discharge. Both weirs set in concrete structure. Small weir crest is 1.0-foot below large weir crest in elevation.

Diversions.—Irrigation ditch diverts low-water discharge at point 300 feet below gage. Station measures waste water and seepage from reservoirs Nos. 2, 3, and 4 and the Luakaha weir.

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Daily discharge, in second-feet, of Nuuanu Stream below reservoir No. 2 wasteway, near Honolulu, Oahu, for 1913.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1		0.21	14.9	16		3.34	11.4
2		.21	45.6	17		1.80	10.6
3		.21	55.4	18		1.83	10.6
4		.21	44.2	19		2.90	10.6
5		.21	30.4	20		27.1	10.6
6		.24	48.3	21	0.30	24.4	9.97
7		.27	36.5	22	.30	17.1	9.01
8		1.08	22.3	23	.30	10.3	7.85
9		1.95	18.9	24	.30	12.1	7.59
10		1.77	13.2	25	.27	20.3	7.35
11		5.05	12.1	26	.27	12.1	6.70
12		5.41	10.6	27	.24	49.4	6.51
13		6.34	9.64	28	.21	24.4	6.51
14		4.38	14.5	29	.21	17.1	6.13
15		3.12	12.5	30	.21	14.1	6.13
				31	.21		6.13

NOTE.—Mean for November, 9.27 second-feet; minimum for November, 0.21 second-feet. Mean for December, 16.9 second-feet; minimum for December, 6.13 second-feet.

LULUMAHA[1] DITCH AT UPPER NUUANU RESERVOIR, NEAR HONOLULU, OAHU.

Location.—About 500 feet east of spillway of upper Nuuanu Valley reservoir, about 7 miles northeast of Honolulu post office.

Records available.—September 2, 1911, to September 30, 1913.

Gage.—Vertical staff.

Control.—Shifting.

Discharge measurements.—Made by wading.

Diversions.—Low-water discharge is diverted from Lulumaha Stream into reservoir No. 4.

Accuracy.—Records poor.

Discharge measurements of Lulumaha ditch at upper Nuuanu reservoir, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Apr. 2	G. K. Larrison	0.31	0.58
14	J. C. Dort	.34	.77

[1] Incorrectly spelled "Lulumaho" in Water-Supply Paper 336.

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Daily discharge, in second-feet, of Lulumaha ditch at upper Nuuanu reservoir, near Honolulu, Oahu, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	0.6	0.5	0.5	1.4	0.9	1.2	3.8	0.5	1.9
2	.5	.5	.5	.7	1.9	.9	3.8	.5	3.8
3	.5	.5	.5	1.2	1.9	6.5	1.9	.5	1.4
4	.5	.5	.5	.7	1.2	.9	1.4	.5	1.4
5	.3	.3	.5	.5	1.2	.9	1.4	.5	1.4
6	.3	2.5	.5	.5	.9	.9	1.4	.5	1.4
7	.3	1.4	.5	.5	5.4	.9	.9	.5	.9
8	.9	1.4	.5	.5	2.0	.9	.9	.5	.9
9	1.2	.9	.5	.5	3.1	1.4	1.2	.5	.9
10	2.9	.6	.5	.5	1.9	3.8	.9	.9	.9
11	8.0	.5	.5	.5	1.4	1.4	.9	.9	.9
12	1.7	.5	.5	2.9	1.4	1.2	.9	1.9	.9
13	1.6	.5	.5	5.8	4.9	1.2	.6	1.4	.9
14	1.0	.5	18.5	1.2	1.2	.9	.6	1.4	1.4
15	1.2	1.4	.9	3.8	2.5	.9	.6	1.9	.9
16	1.9	.9	.6	1.2	1.4	.9	.5	1.4	.6
17	1.4	6.2	.5	1.4	1.4	.9	.5	1.4	.5
18	1.2	1.4	.5	1.2	1.2	.9	.5	1.4	.5
19	1.0	.9	.5	.9	1.2	.9	.5	1.4	1.4
20	.8	.5	.5	.9	1.2	5.4	.5	1.4	.5
21	.8	.5	1.2	.9	1.2	1.2	.5	1.4	.5
22	.6	.5	1.2	.9	1.2	1.2	.5	1.4	.5
23	.6	.5	5.1	1.1	.9	1.2	.5	1.4	.5
24	.6	2.5	1.6	.9	.9	.9	.5	1.4	.5
25	.5	.5	1.0	2.0	.9	.9	.9	1.4	.5
26	.5	.5	1.0	1.4	.9	.9	.9	1.4	.5
27	.5	.5	.9	1.2	1.2	1.2	.6	1.9	.5
28	.5	.5	.5	1.4	1.2	1.4	.6	6.5	.5
29	.5	.....	.5	1.2	1.4	1.4	.9	1.4	.5
30	.5	.....	.5	.9	1.2	3.8	.5	1.4	.5
31	.5	.....	3.8	.....	1.2	.....	.5	1.4	.....

Monthly discharge of Lulumaha ditch at upper Nuuanu reservoir, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	8.0	0.3	1.09	67.0	D.
February	6.2	.3	1.01	56.1	D.
March	18.5	.5	1.48	91.0	D.
April	5.8	.5	1.10	65.5	D.
May	5.4	.9	1.63	100	D.
June	6.5	.9	1.57	93.4	D.
July	3.8	.5	.99	60.9	D.
August	6.5	.5	1.32	81.2	D.
September	3.8	.5	.95	56.5	D.
The period	.....	.....	.....	672	

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PAUOA STREAM AT UPPER PAUOA VALLEY, NEAR HONOLULU, OAHU.

Location.—In upper Pauoa Valley, 1,000 feet below Kahuawai Spring, about 1 mile above Punchbowl, and about 2.5 miles northeast of Honolulu post office.

Records available.—April 14, 1911, to December 31, 1913.

Gage.—Watson weekly water-stage recorder October 17, 1911, to December 31, 1913; staff gage, graduated to tenths and read to hundredths, April 14 to October 16, 1911.

Control.—Permanent.

Discharge measurements.—April 14 to October 16, 1911, current-meter measurements made by wading; October 17, 1911, to December 31, 1913, by 4-foot sharp-crested weir that has been checked with current-meter measurements.

Diversions.—Several small ditches and one pipe line divert part of low-water discharge.

Regulation.—Stream is fed by several perennial springs within 2 miles above station.

Discharge measurements of Pauoa Stream at upper Pauoa Valley, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Mar. 4	G. K. Larrison	0.16	0.91
Sept. 11	G. R. White	.15	.54
Oct. 2	J. C. Dort	.11	.48

Daily discharge, in second-feet, of Pauoa Stream at upper Pauoa Valley, near Honolulu, Oahu, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.19	1.47	0.93	2.41	8.31	1.77	4.16	0.70	0.89	0.55	0.55	2.88
2	2.19	1.37	1.02	1.77	3.50	1.77	6.56	.70	.90	.55	.55	2.76
3	2.08	1.37	.93	1.97	2.41	1.66	3.50	.62	.91	.55	.55	12.5
4	1.97	1.28	.85	2.08	5.29	5.14	2.41	.85	.92	.55	.55	8.14
5	1.97	1.28	.85	1.10	7.64	5.58	3.12	1.02	.93	.55	.55	6.66
6	1.97	1.28	.85	1.10	4.57	2.64	1.97	1.02	.93	.55	.94	6.98
7	1.87	1.37	.77	1.02	3.00	2.53	1.57	1.02	.85	.55	1.32	6.19
8	1.87	1.37	.77	1.02	3.24	2.30	1.57	1.02	.85	.55	1.70	5.29
9	4.85	1.37	.77	.93	3.63	2.08	1.77	.93	.77	.55	2.09	5.29
10	3.37	1.37	.77	.85	3.00	3.24	1.57	.93	.77	.55	2.48	5.14
11	5.43	1.37	.70	.85	2.53	4.16	1.57	.85	.77	.55	2.86	4.57
12	2.53	1.37	.62	3.24	2.19	3.37	1.47	.93	.77	.62	3.24	4.29
13	4.43	1.37	.62	14.1	2.08	2.41	1.47	.93	.77	.70	3.63	4.29
14	3.50	1.37	2.30	3.50	2.30	2.19	1.37	.93	.85	.62	2.08	4.29
15	3.00	1.28	1.02	2.41	2.19	1.97	1.37	.85	.85	.55	1.47	4.29
16	2.64	1.19	.85	1.77	7.47	1.97	1.37	.85	.77	.55	1.19	4.16
17	2.30	1.10	.93	3.89	5.43	1.77	1.37	.77	.77	.55	1.02	4.16
18	2.08	1.10	.85	3.76	2.76	1.77	1.37	.77	.85	.55	2.08	3.76
19	1.97	1.10	.77	2.76	2.19	1.77	1.37	.77	1.10	.55	3.24	3.76
20	1.87	1.10	.77	2.19	1.97	4.16	1.37	.77	.77	.55	6.82	3.76
21	1.77	1.02	.93	1.66	2.08	2.19	1.37	.77	.77	.55	3.76	3.63
22	1.77	1.02	1.19	1.47	2.19	1.77	1.19	.85	.70	.55	1.97	3.63
23	1.66	1.02	1.10	2.19	2.08	1.57	1.37	.85	.70	.55	1.66	3.54
24	1.66	.93	1.02	3.63	1.87	1.57	1.77	.77	.70	.55	3.76	3.46
25	1.66	1.02	.93	8.48	1.77	1.47	1.37	.77	.70	.55	16.2	3.37
26	1.66	1.02	.85	2.41	1.97	1.47	1.19	.85	.62	.55	12.9	3.24
27	1.57	1.02	.93	1.87	1.97	1.47	1.02	.85	.62	.55	5.58	3.00
28	1.57	1.02	.93	3.63	1.97	3.37	1.37	.85	.55	.55	3.37	2.88
29	1.57	.....	1.02	4.29	1.97	1.97	1.28	.86	.62	.55	2.76	2.88
30	1.57	.....	.93	2.19	1.97	2.64	1.28	.87	.62	.55	3.24	2.76
31	1.47	.....	3.63	.....	1.87	.....	.70	.88	.....	.55	.....	2.64

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Monthly discharge of Pauoa Stream at upper Pauoa Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	5.43	1.47	2.32	143	A.
February	1.47	.93	1.21	67.2	A.
March	3.63	.62	1.01	62	A.
April	14.1	.85	2.82	168	A.
May	8.31	1.77	3.14	193	A.
June	5.58	1.47	2.44	146	A.
July	6.56	.7	1.81	111	A.
August	1.02	.62	.85	52.3	A.
September	1.1	.55	.79	47	A.
October	.7	.55	.56	34.4	D.
November	16.2	.55	3.14	187	C.
December	12.5	2.64	4.46	274	A.
The year	16.2	.55	2.05	1,480	

KAHUAWAI SPRING AT UPPER PAUOA VALLEY, NEAR HONOLULU, OAHU.

Location.—In upper Pauoa Valley, one-fourth mile above Pauoa Stream weir station, about 1¼ miles above Punchbowl, and about 2¾ miles northeast of Honolulu post office.

Records available.—September 23, 1912, to December 31, 1913.

Gage.—A 2 by 2 inch stake driven into pool of spring, with nail in top, 6 feet above weir, to measure head on weir. Head is read twice daily to hundredths.

Control.—Spring boils up vertically in pool about 10 feet in diameter. Weir is built between rock abutments on south side of pool about 10 feet from center.

Discharge.—Computed by Francis formula for sharp-crested weirs with end contractions. Weir has 1.5-foot crest length.

Monthly discharge of Kahuawai Spring at upper Pauoa Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	0.54	0.50	0.50	30.7	A.
February	.50	.47	.50	27.8	A.
March	.50	.47	.48	29.5	A.
April	.50	.50	.50	29.8	A.
May	.54	.50	.51	31.4	A.
June	.54	.50	.52	30.9	A.
July	.54	.50	.50	30.7	A.
August	.50	.50	.50	30.7	A.
September	.50	.50	.50	29.8	A.
October	.50	.50	.50	30.7	A.
November	.54	.50	.53	31.5	A.
December	.54	.54	.54	33.2	A.
The year	.54	.47	.51	367	

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MANOA STREAM AT UPPER MANOA VALLEY, NEAR HONOLULU, OAHU.

Location.—Below confluence of two main branches in upper Manoa Valley, about 5 miles east of Honolulu post office.

Records available.—October 6, 1910, to July 5, 1913.

Gage.—Vertical staff.

Control.—Shifting.

Discharge measurements.—Made by wading for low and medium stages up to a gage height of about 4.0 feet; above this stage from footbridge at gage.

Diversions.—Several small irrigation ditches divert a part of the low-water discharge from the branches of the stream above the station. Most of this water returns to the stream by seepage and drains above the station.

Accuracy.—Records poor.

Discharge measurements of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec. ft.*			*Feet.*	*Sec. ft.*
Feb. 28	G. K. Larrison	2.93	1.08	Apr. 14	J. C. Dort	3.70	18.5
Mar. 21	J. C. Dort	3.36	6.06				

Monthly discharge of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	5.1	1.2	2.43	149	D.
February	12.2	1.1	2.70	150	D.
March	15	1.1	3.40	209	D.
April	33	2.5	11.5	684	D.
May	39	7.9	13.6	836	D.
June	38	7.2	12.2	726	D.
July 1–5	13	10	11.6	115	D.
The period				2,870	

NOTE.—Two stations were established on the east and west branches of Manoa Stream May 29, 1913. These stations are above all diversions and are intended to supplant the old station, which was discontinued July 5, 1913.

MANOA STREAM AT COLLEGE OF HAWAII, NEAR HONOLULU, OAHU.

Location.—In gorge about one-half mile southeast of College of Hawaii, and 3 miles east of Honolulu post office.

Records available.—Daily discharge from March 23, 1909, to November 24, 1910; November 1, 1912, to April 26, 1913; September 10 to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—Several irrigation ditches above station.

Accuracy.—Records poor.

Cooperation.—Maintained in cooperation with the College of Hawaii.

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Discharge measurements of Manoa Stream at College of Hawaii, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec. ft.*			*Feet.*	*Sec. ft.*
Feb. 28	G. K. Larrison	0.95	0.99	Apr. 14	J. C. Dort	2.40	39.4
Mar. 21	J. C. Dort	2.09	26.0	17	Dort and White	2.64	56.7

Daily discharge, in second-feet, of Manoa Stream at College of Hawaii, near Honolulu, Oahu, for 1912–13.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1912.			1912.			1912.		
1	2.6	35	11	4.8	4.0	21	33	20
2	2.0	38	12	5.5	2.0	22	35	106
3	3.0	169	13	2.0	3.5	23	38	33
4	1.1	29	14	1.2	3.5	24	18	155
5	3.9	22	15	6.2	2.0	25	11	20
6	2.0	19	16	2.5	1.8	26	7.0	45
7	7.0	17	17	2.0	1.5	27	7.0	29
7	3.0	11	18	2.2	1.8	28	62	20
9	29	7.0	19	2.3	31	29	33	7.0
10	3.8	7.0	20	2.0	6.7	30	14	7.0
						31	.....	7.0

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	7.0	0.9	1.0	5.8	.....	.....	.....	.....	.....	0.5	0.6	11
2	7.0	1.2	.9	6.4	.....	.....	.....	.....	.....	.5	1.5	8.0
3	3.2	1.4	.9	4.3	.....	.....	.....	.....	.....	.5	2.5	44
4	2.0	1.3	1.2	3.1	.....	.....	.....	.....	.....	.5	1.0	102
5	2.0	1.0	1.4	2.4	.....	.....	.....	.....	.....	.5	.8	41
6	2.0	1.9	1.2	1.9	.....	.....	.....	.....	.....	.5	.9	44
7	2.0	6.7	1.2	1.9	.....	.....	.....	.....	.....	.5	1.0	65
8	2.0	6.1	1.1	2.6	.....	.....	.....	.....	.....	.5	15	28
9	4.0	2.6	1.2	2.5	.....	.....	.....	.....	.....	.5	31	18
10	7.0	1.8	1.3	20	.....	.....	.....	.....	0.6	.5	32	12
11	10	1.6	1.2	13	.....	.....	.....	.....	.5	.5	36	9.4
12	6.0	1.2	1.2	21	.....	.....	.....	.....	.5	.4	31	7.8
13	14	1.0	1.2	57	.....	.....	.....	.....	.6	.4	27	7.0
14	18	.9	6.4	37	.....	.....	.....	.....	1.2	.7	12	8.0
15	12	.9	8.0	48	.....	.....	.....	.....	1.0	.6	9.4	6.4
16	6.4	.9	6.4	64	.....	.....	.....	.....	.7	.6	3.8	4.8
17	4.6	1.0	3.4	33	.....	.....	.....	.....	.7	.6	4.6	4.6
18	3.6	9.0	2.6	24	.....	.....	.....	.....	.7	.5	6.7	5.8
19	3.4	11	1.8	24	.....	.....	.....	.....	4.9	.5	23	3.9
20	2.8	3.2	4.4	19	.....	.....	.....	.....	1.1	.5	61	3.1
21	6.1	1.2	3.6	13	.....	.....	.....	.....	.8	.5	31	3.1
22	4.8	1.0	10	9.8	.....	.....	.....	.....	.8	.5	9.8	2.8
23	4.9	1.8	4.6	18	.....	.....	.....	.....	.8	.5	9.4	1.9
24	4.3	2.7	3.4	8.4	.....	.....	.....	.....	.7	.5	32	1.4
25	3.0	3.2	3.1	67	.....	.....	.....	.....	.7	.5	75	1.0
26	2.6	2.4	3.3	18	.....	.....	.....	.....	.6	.5	141	.9
27	2.0	1.6	2.2	.....	.....	.....	.....	.....	.6	.5	50	.9
28	2.0	1.0	2.8	.....	.....	.....	.....	.....	.5	.6	27	.9
29	1.9	.....	3.7	.....	.....	.....	.....	.....	.5	.6	18	.8
30	.9	.....	15	.....	.....	.....	.....	.....	.5	.6	17	.8
31	2.0	.....	11	.....	.....	.....	.....	.....	.....	.6	.....	.7

NOTE.—No record Apr. 27 to Sept. 9, 1913.

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Monthly discharge of Manoa Stream at College of Hawaii, near Honolulu, Oahu, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
November	62	1.1	11.5	684	C.
December	169	1.5	27.8	1,710	D.
1913.					
January	18	0.9	4.95	304	C.
February	11	.9	2.52	140	C.
March	15	.9	3.57	220	C.
April 1–26	67	1.9	2.02	1,040	B.
September 10–30	4.9	.5	.90	38	
October	.7	.4	.52	32	D.
November	141	.6	23.7	1,410	C.
December	102	.7	14.5	892	C.
The period				4,080	

EAST BRANCH OF MANOA STREAM AT UPPER MANOA VALLEY, NEAR HONOLULU, OAHU.

Location.—About 4 miles northeast of Honolulu post office, in upper Manoa Valley, about 200 feet above highway bridge, and 600 feet above confluence of two branches.

Records available.—May 29 to December 31, 1913.

Gage.—Vertical staff.

Control.—Somewhat shifting at high water.

Diversions.—One irrigation ditch diverts water above station.

Discharge measurements.—For low and medium stages, made by wading just below highway bridge; for floods, from bridge.

Accuracy.—Records good.

Discharge measurements of East Branch of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 23	G. K. Larrison	2.19	2.41	Nov. 12	J. C. Dort	2.84	10.2
Sept. 11	....do	2.07	1.63	Dec. 4	G. R. White	3.38	24.0
Nov. 10	J. C. Dort	2.54	4.91				

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Daily discharge, in second-feet, of East Branch of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.9	2.1	1.8	1.7	1.6	1.5	3.0
2	.....	1.9	2.1	1.8	2.0	1.5	1.8	4.5
3	.....	19	2.1	1.7	1.8	1.5	1.6	20
4	.....	3.2	2.1	1.7	1.7	1.5	1.5	23
5	.....	2.6	2.1	1.7	1.7	1.6	1.6	14
6	.....	2.7	2.0	1.8	5.4	1.6	1.6	14
7	.....	2.6	2.0	1.8	1.7	1.7	15	18
8	.....	2.6	2.0	1.7	1.7	2.1	7.8	5.2
9	.....	3.3	2.0	1.7	1.6	1.6	7.4	7.4
10	.....	3.7	2.0	2.2	1.6	1.6	3.8	5.8
11	.....	3.0	2.0	1.8	1.6	1.5	4.3	5.7
12	.....	2.3	2.0	5.6	1.7	1.5	7.4	5.3
13	.....	2.1	2.2	2.0	1.9	1.9	6.6	5.2
14	.....	2.0	2.3	1.9	1.7	1.8	4.5	4.8
15	.....	2.0	2.0	1.8	1.6	1.6	3.2	4.6
16	.....	2.0	1.9	1.8	1.6	2.0	2.4	4.2
17	.....	2.0	1.9	2.2	1.5	1.6	2.4	3.8
18	.....	2.0	1.9	1.9	1.7	1.5	4.8	3.6
19	.....	2.3	1.8	1.8	2.1	1.5	8.3	3.0
20	.....	88	1.8	1.8	1.6	1.5	45	3.4
21	.....	2.2	1.8	1.9	1.8	1.5	8.8	3.3
22	.....	2.1	1.8	1.9	1.7	1.5	5.6	3.0
23	.....	2.0	1.8	2.0	1.6	1.5	4.4	2.8
24	.....	2.0	1.8	2.0	1.6	1.5	4.3	2.8
25	.....	2.1	1.9	2.0	1.6	1.5	14	2.8
26	.....	2.1	2.0	2.0	1.5	1.5	17	2.8
27	.....	2.1	1.8	1.9	1.5	1.6	15	2.8
28	.....	2.0	2.0	2.2	1.7	1.6	8.3	2.8
29	2.2	2.0	1.8	2.0	1.6	1.5	6.1	2.8
30	2.0	2.1	1.8	2.0	1.6	1.6	5.8	2.8
31	1.9	.....	1.8	3.6	.....	1.5	.....	2.8

NOTE.—Discharge July 1-10 estimated by comparison with other stream run-off in vicinity.

Monthly discharge of East Branch of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May 29-31	2.2	1.9	2.03	12.1	B.
June	88	1.9	5.72	340	B.
July	2.3	1.8	1.95	120	B.
August	5.6	1.7	2.06	127	B.
September	5.4	1.5	1.80	107	B.
October	2.1	1.5	1.60	98.4	B.
November	45	1.5	7.39	440	B.
December	23	2.8	6.13	377	B.
The period	.....	.....	.....	1,620	

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WEST BRANCH OF MANOA STREAM AT UPPER MANOA VALLEY, NEAR HONOLULU, OAHU.

Location.—About 150 feet above highway bridge in upper Manoa Valley, and 4 miles northeast of Honolulu post office.

Records available.—May 29 to December 31, 1913.

Gage.—Vertical staff.

Control.—Somewhat shifting.

Discharge measurements.—At low and medium stages made by wading; flood measurements made from footbridge.

Diversions.—None above station.

Accuracy.—Records good.

Discharge measurements of West Branch of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 23	G. K. Larrison	1.84	2.44	Nov. 10	J. C. Dort	2.62	10.1
Sept. 11	do	1.53	.68	Nov. 12	do	2.95	19.2

Daily discharge, in second-feet, of West Branch of Manoa Stream, at upper Manoa Valley, near Honolulu, Oahu, for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.4	1.9	1.3	4.0	0.6	0.4	4.7
2	.....	1.2	2.0	1.4	2.6	.2	.8	4.5
3	.....	14	2.0	1.5	1.4	.5	1.0	14
4	.....	3.4	2.1	1.4	1.2	.5	.7	18
5	.....	2.4	2.1	1.8	1.3	.6	.6	10
6	.....	2.6	2.2	1.3	1.0	.6	.6	11
7	.....	1.8	2.2	1.5	.8	.7	6.0	8.2
8	.....	1.3	2.3	1.1	.7	3.5	8.2	6.8
9	.....	4.4	2.3	1.2	.6	.8	13	4.6
10	.....	5.4	2.4	3.5	.6	.6	9.2	4.6
11	.....	4.0	2.5	1.3	.6	.5	12	4.3
12	.....	3.1	2.4	8.0	.7	.5	15	8.6
13	.....	6.4	2.3	2.0	1.6	.8	10	4.1
14	.....	16	1.8	1.6	1.6	.4	5.8	3.5
15	.....	16	2.0	1.2	.8	.7	4.7	1.3
16	.....	2.3	1.9	1.2	.7	2.2	4.1	.1
17	.....	2.1	1.3	2.5	.6	.6	4.3	1.4
18	.....	2.2	1.6	1.4	1.1	.5	5.4	.1
19	.....	3.5	1.4	1.1	3.4	.5	10	.8
20	.....	68	1.6	1.2	1.6	.5	22	3.8
21	.....	3.4	1.7	1.0	1.2	.4	9.7	4.0
22	.....	2.6	1.4	.9	.9	.4	6.4	1.8
23	.....	2.1	1.8	.9	.9	.4	4.3	3.0
24	.....	1.9	2.7	.9	.9	.4	9.4	2.6
25	.....	1.9	1.7	.9	.8	.4	8.5	2.5
26	.....	1.9	1.5	.7	.7	.4	23	2.4
27	.....	1.9	2.0	.7	.6	.7	17.0	2.3
28	.....	2.6	1.7	1.2	.5	1.4	9.2	2.1
29	1.6	1.7	2.0	1.7	.8	.6	7.3	2.0
30	1.6	1.8	1.9	1.1	.6	.4	5.6	2.0
31	4.6	.....	1.8	3.5	.....	.4	.....	1.9

NOTE.—Discharge estimated July 1-10.

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Monthly discharge of West Branch of Manoa Stream at upper Manoa Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May 29-31	4.6	1.6	2.60	15.5	B.
June	68	1.2	6.11	364	B.
July	2.7	1.3	1.95	120	B.
August	8.0	.7	1.65	101	B.
September	4.0	.5	1.16	69	B.
October	3.5	.2	.70	43	B.
November	23	.4	7.81	465	B.
December	18	.1	4.55	280	B.
The period				1,460	

WAIOMAO STREAM AT UPPER PALOLO VALLEY, NEAR HONOLULU, OAHU.

Location.—About 3 miles above Pukele in Palolo Valley, and about 9 miles from Honolulu post office, at an elevation of 900 feet.

Records available.—October 10, 1911, to July 12, 1913.

Gage.—Watson water-stage recorder above 3-foot sharp-crested weir; datum uncertain on account of leaks under weir.

Control.—Shifting.

Discharge measurements.—Made by wading.

Diversions.—New pipe line diverted all low-water discharge for Honolulu water supply after July 12, 1913.

Accuracy.—Records fair.

Regulation.—Stream drains Kaau Crater and is regulated by springs.

Discharge measurements of Waiomao Stream at upper Palolo Valley, near Honolulu, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Feb. 26	G. K. Larrison	0.12	0.49
Apr. 8	do	.08	.29

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Daily discharge, in second-feet, of Waiomao Stream at upper Palolo Valley, near Honolulu, Oahu, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1	0.37	0.19	0.37	0.96	0.58	0.32	1.24
2	.27	.19	.37	.70	1.10	.37	1.56
3	.27	.19	.37	.70	1.17	4.30	1.17
4	.27	.42	.32	.58	.82	3.02	.89
5	.52	4.08	.32	.47	.64	1.56	.89
6	.32	1.64	.32	.37	.47	1.32	.64
7	.27	1.48	.52	.32	1.10	.89	.70
8	.23	1.72	.47	.32	3.64	.76	.52
9	.27	.82	.37	.32	1.64	.70	.52
10	.37	.58	.32	.32	1.24	.64	.42
11	.89	.47	.32	.76	1.03	.52	.42
12	.58	.37	.27	1.24	4.88	.82	.52
13	.70	.32	.27	4.08	3.75	1.03	.....
14	.58	.27	3.32	2.52	2.34	.76	.....
15	.64	1.89	2.07	1.80	2.16	1.64	.....
16	.70	2.52	1.17	3.22	1.72	2.82	.....
17	.42	2.16	.89	3.22	1.56	2.16	.....
18	.47	3.02	.64	1.89	1.17	1.24	.....
19	.47	2.25	.52	1.40	1.03	1.03	.....
20	.42	1.32	.47	1.10	.76	1.64	.....
21	.37	.89	1.64	.82	.64	1.03	.....
22	.37	.70	1.89	.82	.58	.76	.....
23	.32	.64	1.32	1.10	.53	.64	.....
24	.27	.89	1.98	1.03	.48	.52	.....
25	.23	.64	1.72	5.48	.42	.47	.....
26	.19	.58	1.17	1.80	.37	.47	.....
27	.23	.52	1.10	1.10	.52	1.64	.....
28	.19	.42	.76	.96	.37	3.12	.....
29	.19	.....	.64	.82	.37	1.48	.....
30	.19	.....	1.10	.64	.37	1.48	.....
31	.27	.....	.89	.....	.32	.....	.....

NOTE.—Discharge May 22-24 estimated.

Monthly discharge of Waiomao Stream at upper Palolo Valley, near Honolulu, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	0.89	0.19	0.38	23.4	C.
February	4.08	.19	1.11	61.6	C.
March	3.32	.27	.90	55.3	C.
April	5.48	.32	1.36	80.9	C.
May	4.88	.32	1.22	75.0	C.
June	4.30	.32	1.30	77.4	C.
July 1-12	1.56	.42	.79	18.8	C.
The period	.....	.....	.....	390	

WAIMANALO DITCH BELOW MAIN RESERVOIR ON THE WAIMANALO PLANTATION, NEAR WAIMANALO, OAHU.

Location.—On main ditch immediately below main reservoir of the Waimanalo plantation, about 2 miles southwest of the plantation headquarters. Waimanalo is about 15 miles east of Honolulu.

Records available.—November 1, 1912, to December 31, 1913.

Gage.—Vertical staff, read twice daily to quarter-tenths.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—Ditch is outlet of the main reservoir on the Waimanalo plantation.

Accuracy.—Records good.

Cooperation.—Maintained in cooperation with the Waimanalo Plantation Co.

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Discharge measurements of Waimanalo ditch below main reservoir on the Waimanalo plantation, near Waimanalo, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Apr. 11	G. K. Larrison	1.18	6.15
Sept. 9	G. R. White	1.42	7.53

Daily discharge, in second-feet, of Waimanalo ditch below main reservoir on the Waimanalo plantation, near Waimanalo, Oahu, for 1912–13.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1912.			1912.			1912.		
1	6.9	7.4	11	7.5	.....	21	7.1	.....
2	6.7	7.4	12	7.3	.....	22	7.3	.....
3	6.9	7.4	13	7.0	.....	23	6.9	.....
4	7.1	7.4	14	7.0	.....	24	7.1	.....
5	7.2	7.4	15	7.3	.....	25	7.3	.....
6	6.9	7.4	16	6.9	.....	26	7.0	.....
7	6.9	7.4	17	7.1	.....	27	7.3	.....
8	6.6	7.4	18	7.3	.....	28	6.9	.....
9	7.2	7.4	19	7.3	.....	29	7.4	.....
10	7.4	.....	20	6.9	.....	30	7.4	.....
						31	.....	.....

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	7.0	.....	.....	6.2	6.8	6.7	7.4	7.3	7.3	6.8	6.8	7.4
2	6.7	.....	.....	6.2	7.4	7.3	6.9	6.9	7.3	6.8	7.1	7.4
3	6.9	.....	6.8	6.2	7.4	.....	6.9	7.2	6.8	6.8	7.4	7.4
4	7.1	.....	6.8	6.2	5.1	.....	7.1	7.4	6.8	6.8	7.4	7.4
5	.....	.....	6.8	6.2	7.3	.....	6.9	7.4	6.8	7.1	6.8	.....
6	.....	.....	6.8	6.2	7.3	.....	7.2	6.9	6.8	7.4	6.8	.....
7	.....	.....	6.8	6.2	7.3	.....	7.5	6.8	7.0	7.1	6.8	.....
8	.....	.....	6.7	6.2	7.4	.....	7.4	6.8	7.3	6.8	6.8	.....
9	.....	.....	6.8	6.2	7.3	7.3	7.8	6.8	7.3	6.8	7.1	.....
10	.....	.....	6.8	6.2	7.3	7.3	7.5	7.1	6.8	6.8	7.4	.....
11	.....	.....	6.8	6.2	6.7	.....	7.5	7.4	6.8	6.8	7.1	.....
12	.....	.....	6.8	6.2	.....	.....	7.3	7.4	6.8	7.1	6.8	.....
13	.....	.....	6.8	6.2	.....	.....	7.6	7.4	6.8	7.4	6.8	.....
14	.....	.....	6.8	6.2	.....	.....	7.8	7.4	7.0	7.1	6.8	.....
15	.....	.....	.....	6.2	.....	.....	7.5	7.4	7.3	6.8	6.8	.....
16	.....	.....	5.6	6.2	.....	6.8	7.5	6.8	7.3	6.8	7.1	.....
17	.....	.....	5.6	6.2	.....	6.8	7.4	7.1	6.8	6.8	7.4	.....
18	.....	.....	6.8	6.2	.....	6.2	7.4	7.4	6.8	6.8	7.4	.....
19	.....	.....	6.8	6.2	.....	6.2	7.3	7.1	6.8	7.1	7.1	.....
20	.....	.....	6.8	6.2	6.2	6.2	7.4	7.1	6.8	7.4	6.8	.....
21	.....	.....	6.8	6.3	6.2	6.5	7.5	7.1	7.0	7.1	6.8	.....
22	.....	.....	6.8	6.3	6.7	6.1	7.5	7.1	7.3	6.8	6.8	.....
23	.....	.....	6.8	6.3	6.9	6.9	7.4	6.8	7.3	6.8	7.1	.....
24	.....	.....	6.8	6.3	7.4	6.9	7.3	7.1	6.8	6.8	7.4	.....
25	.....	.....	6.5	6.5	6.3	6.7	7.3	7.4	6.8	6.8	7.4	.....
26	.....	.....	6.2	6.5	7.3	6.9	6.9	7.4	6.8	7.1	7.4	.....
27	.....	.....	6.2	5.6	7.4	7.1	6.9	7.1	6.8	7.4	7.4	.....
28	.....	.....	6.2	6.8	6.9	7.1	6.9	7.1	7.0	7.4	7.4	.....
29	.....	.....	6.2	6.2	6.9	6.2	6.9	6.9	7.3	6.8	7.4	.....
30	.....	.....	6.2	7.4	7.4	7.3	6.9	6.8	7.1	6.8	.....	.....
31	.....	.....	6.2	.....	7.3	.....	6.9	7.0	.....	6.8	.....	.....

NOTE.—Ditch dry Dec. 10–31, 1912; Jan. 5 to Mar. 2, May 12–19, June 3–8, 11–15, and Dec. 6–31, 1913. Discharge given is for period of about 10 hours daily. During remaining 14 hours ditch was dry. Discharge interpolated Sundays from July to December, as gage was not read.

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Monthly discharge of Waimanalo ditch below main reservoir on the Waimanalo plantation, near Waimanalo, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 1-4	7.1	6.7	6.92	22.9	B.
February	.....	.....	.....	.....	
March 3-14, 16-31	6.8	5.6	6.57	152	B.
April	7.4	5.6	6.27	155	B.
May 1-11, 20-31	7.4	5.1	6.97	132	B.
June 1, 2, 9, 10, 16-30	7.3	6.1	6.76	106	B.
July	7.8	6.9	7.28	187	B.
August	7.4	6.8	7.13	183	B.
September	7.3	6.8	6.99	173	B.
October	7.4	6.8	6.96	178	B.
November	7.4	6.8	7.09	408	B.
December 1-4	7.4	7.4	7.40	58.7	B.
The period	.....	.....	.....	1,760	

NOTE.—Ditch dry during February. Water turned out of ditch Dec. 4.

MAKAWAO DITCH AT MAKAWAO FLUME, NEAR WAIMANALO, OAHU.

Location.—At west end of flume in Kailua Valley, 4 miles west of Waimanalo, and 11 miles by road from Honolulu; previous to November 24, 1913, at east end of flume.

Records available.—November 1, 1912, to December 31, 1913.

Gage.—Staff; new datum beginning November 24, 1913.

Control.—Practically permanent.

Discharge measurements.—November 1, 1912, to November 23, 1913, made by current-meter in open flume; November 24 to December 31, 1913, by 2.5-foot sharp-crested weir with end contractions.

Diversions.—Ditch diverts all low water from headwaters of Kaimi and Makawao streams and discharges into the Waimanalo Reservoir.

Accuracy.—Records poor.

Cooperation.—Observer furnished by Waimanalo Plantation Co.

Discharge measurements of Makawao ditch at Makawao flume, near Waimanalo, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	0.59	3.03	Oct. 20	J. C. Dort	0.65	1.79
Sept. 9	G. R. White	.70	1.96				

Monthly discharge of Makawao ditch at Makawao flume, near Waimanalo, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
March 3-31	5.4	2.0	3.75	216	D.
April	7.3	3.0	4.08	243	D.
May	7.9	2.6	3.88	239	D.
June	4.4	2.3	3.16	188	D.
July	3.2	1.9	2.43	149	D.
August	3.2	2.1	2.57	158	D.
September	2.7	1.6	1.97	117	D.
October	2.1	1.6	1.95	120	D.
November	6.0	1.9	3.29	196	D.
December 1-3	3.6	1.9	2.97	17.1	D.
The period (276 days)	7.9	1.6	3.00	1,640	

NOTE.—Ditch dry Jan. 1 to Mar. 2 and Dec. 4-31.

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MAKAWAO STREAM IN KAILUA VALLEY, NEAR KAILUA, OAHU.

Location.—One-fourth mile upstream from confluence of Makawao and Kaimi streams, and 100 feet above intake of irrigation ditch on Waimanalo-Honolulu road; about 12½ miles east by road from Honolulu.

Records available.—November 12, 1912, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading and from footbridge.

Diversions.—Low-water discharge of two main branches is diverted into Makawao ditch about three-fourths mile above station. An irrigation ditch diverts most of the low-water discharge at a point about 100 feet below the gage.

Accuracy.—Records fair.

Cooperation.—Maintained in cooperation with the Kaneohe Ranch Co.

Discharge measurements of Makawao Stream in Kailua Valley, near Kailua, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	0.94	1.92	Sept. 9	J. C. Dort	0.90	1.81
June 4	do	1.37	9.11	Dec. 10	G. R. White	1.32	7.09

Daily discharge, in second-feet, of Makawao Stream in Kailua Valley, near Kailua, Oahu, for 1912–13.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1912.			1912.			1912.		
1		11	11		2.2	21	1.3	1.7
2		27	12	1.0	2.3	22	1.3	2.1
3		44	13	1.0	2.2	23	1.1	1.8
4		4.4	14	1.1	1.9	24	1.1	1.8
5		3.7	15	1.1	1.9	25	1.1	1.7
6		1.4	16	1.1	1.9	26	1.1	1.7
7		2.1	17	1.0	1.9	27	1.1	1.7
8		2.3	18	1.0	2.2	28	1.6	1.7
9		2.6	19	1.1	2.2	29	1.3	1.7
10		2.2	20	1.0	1.9	30	1.1	1.7
						31		

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Daily discharge, in second-feet, of Makawao Stream in Kailua Valley, near Kailua, Oahu, for 1912–13—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	.....	2.2	3.1	2.3	1.9	2.7	2.5	2.1	2.3	1.6	1.6	2.5
2	.....	2.2	3.6	2.3	2.5	2.8	3.4	1.9	3.4	1.6	1.6	2.1
3	.....	2.1	2.7	2.5	1.9	20	2.5	2.1	2.1	1.7	1.6	2.5
4	.....	1.9	2.9	2.5	1.9	17	2.5	1.9	2.1	1.6	1.6	27
5	.....	3.1	2.7	2.9	1.7	4.3	2.3	1.7	1.7	1.6	1.6	26
6	.....	11	2.9	3.4	1.7	3.8	2.1	1.7	1.8	1.6	1.4	9.2
7	.....	6.8	1.9	3.1	2.1	3.7	2.3	1.9	1.7	1.6	1.4	23
8	.....	4.1	1.8	2.5	2.1	3.6	2.3	2.1	1.6	1.6	1.7	13
9	.....	3.2	1.9	2.3	2.9	3.0	2.3	2.1	1.6	1.6	1.3	8.1
10	.....	2.5	2.2	2.1	3.6	3.1	2.3	1.9	1.6	1.6	1.6	6.5
11	.....	1.6	1.9	2.1	2.0	3.0	2.3	1.9	1.6	1.6	1.6	5.4
12	.....	1.4	1.6	2.2	48	2.9	2.1	4.1	1.6	1.6	1.5	4.8
13	.....	.9	1.1	2.4	12	3.1	2.1	2.9	1.7	1.6	1.6	4.4
14	1.1	1.6	1.3	2.1	15	3.1	2.5	2.1	1.7	1.6	1.5	3.7
15	1.1	2.5	1.1	2.1	16	3.1	2.5	1.9	1.7	1.6	1.4	3.6
16	19	11	1.0	6.1	3.4	3.2	2.2	1.9	1.6	1.6	1.6	3.1
17	1.6	14	14	2.8	4.4	2.8	2.4	2.3	1.6	1.6	1.6	3.6
18	1.4	14	5.1	2.1	4.0	2.6	2.3	2.5	1.6	1.6	1.6	4.1
19	16	9.9	4.6	2.0	3.6	2.7	2.3	2.2	1.6	1.6	1.7	4.1
20	7.6	11	3.6	1.8	2.5	3.1	2.1	2.1	1.6	1.6	2.3	4.0
21	15	9.4	3.1	1.9	2.6	2.9	1.9	2.1	1.6	1.6	2.3	3.7
22	2.9	6.3	2.3	2.1	2.4	2.5	1.9	1.9	1.7	1.5	2.3	3.6
23	2.7	3.2	1.8	1.9	2.3	2.3	1.9	2.1	1.9	1.7	1.9	3.4
24	2.5	2.7	3.1	1.9	2.3	2.4	1.9	2.1	1.7	1.8	1.7	3.1
25	2.1	4.1	2.8	1.9	2.6	2.4	1.9	2.1	1.7	1.7	2.1	3.1
26	2.6	4.1	3.2	1.7	2.4	2.5	1.9	2.1	1.6	1.6	4.8	2.8
27	1.9	3.6	4.4	1.6	2.5	2.4	1.9	2.0	1.6	1.6	1.9	3.1
28	1.9	2.9	3.6	1.6	2.4	2.5	2.1	2.0	1.6	1.7	1.7	3.1
29	2.2	.....	2.6	1.7	2.4	2.6	2.1	1.9	1.6	1.6	1.6	3.1
30	2.2	.....	2.6	.8	2.4	2.4	1.9	2.0	1.6	1.4	1.9	3.1
31	3.2	.....	2.5	.....	2.6	.....	1.9	2.1	.....	1.4	.....	3.1

NOTE.—No record January 1–13.

Monthly discharge of Makawao Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 14–31	19	1.1	4.83	172	B.
February	14	.9	5.14	285	B.
March	14	1.0	3.00	184	B.
April	6.1	.8	2.29	136	B.
May	48	1.7	5.16	317	B.
June	20	2.3	3.95	235	B.
July	3.4	1.9	2.21	136	B.
August	4.1	1.9	2.12	130	B.
September	3.4	1.6	1.76	105	B.
October	1.8	1.4	1.60	98	B.
November	4.8	1.3	1.80	107	B.
December	27	2.1	6.32	389	B.
The period	.....	.....	.....	2,290	

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KAIMI STREAM IN KAILUA VALLEY, NEAR KAILUA, OAHU.

Location.—At highway bridge on Waimanalo-Honolulu government road, about 12½ miles east of Honolulu.

Records available.—November 12, 1912, to December 31, 1913.

Gage.—Vertical staff, read twice daily. Datum raised 1.00 foot April 10, 1913; that is, 1.50 feet gage height previous to April 10 equals 0.50 foot gage heights after that date.

Control.—Fairly permanent.

Discharge measurements.—During low water, made by wading; during floods, from bridge.

Diversions.—Headwaters diverted by Makawao ditch.

Accuracy.—Records poor.

Cooperation.—Maintained in cooperation with the Kaneohe Ranch Co.

Discharge measurements of Kaimi Stream in Kailua Valley, near Kailua, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	0.75	1.12	Sept. 9	J. C. Dort	0.82	1.67
June 4	do	1.08	5.55				

Daily discharge, in second-feet, of Kaimi Stream in Kailua Valley, near Kailua, Oahu, for 1912–13.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1912.			1912.			1912.		
1		18	11		1.5	21	1.5	2.6
2		1.7	12	1.0	.8	22	1.6	2.5
3		21	13	1.0	.8	23	1.3	2.4
4		4.3	14	1.0	.8	24	1.1	2.6
5		4.0	15	1.8	2.4	25	1.2	2.6
6		1.9	16	1.0	2.5	26	1.1	2.6
7		2.4	17	1.0	2.6	27	1.6	2.6
8		2.5	18	1.0	2.5	28	2.8	2.0
9		2.5	19	1.1	3.4	29	2.6	2.0
10		2.6	20	1.0	2.5	30	1.9	2.0
						31		2.4

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Daily discharge, in second-feet, of Kaimi Stream in Kailua Valley, near Kailua, Oahu, for 1912–13—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	.....	2.0	2.9	1.4	1.2	1.5	1.9	1.6	3.2	1.4	1.4	2.9
2	.....	2.0	2.8	1.4	2.2	1.5	2.4	1.5	4.3	1.4	1.5	2.5
3	.....	1.7	2.4	1.4	1.3	12	1.7	1.5	1.9	1.4	1.5	2.6
4	.....	1.7	2.4	1.4	1.2	9.6	1.8	1.5	1.5	1.4	1.5	23
5	.....	3.2	2.8	1.7	1.5	3.6	1.8	1.5	1.7	1.4	1.5	24
6	.....	10	2.4	2.2	1.2	4.8	1.7	1.4	1.6	1.4	1.4	15
7	.....	8.4	1.9	1.7	1.4	4.1	1.5	1.4	1.7	1.5	1.5	25
8	.....	3.4	1.6	1.2	15	3.6	1.7	1.5	1.6	1.5	2.9	13
9	.....	2.4	1.4	.9	16	2.4	1.7	1.4	1.4	1.4	2.4	7.8
0	.....	1.5	2.4	1.0	14	2.5	1.5	1.5	1.5	1.5	1.7	5.5
11	.....	.9	2.4	1.2	1.4	2.8	1.5	1.4	1.5	1.5	1.7	5.2
12	.....	1.2	1.7	1.7	26	2.9	1.5	2.9	1.4	1.5	1.7	4.1
13	.....	.7	1.6	3.8	10	4.0	1.5	1.9	1.5	1.5	1.7	4.0
14	0.8	1.4	1.4	1.2	18	4.1	1.5	1.4	1.6	1.5	1.5	3.6
15	.8	2.6	.9	1.2	19	4.5	1.5	1.4	1.5	1.5	1.5	3.5
16	10	12	.8	4.8	3.5	4.1	1.5	1.5	1.4	1.5	1.6	3.2
17	1.2	7.0	14	1.3	5.0	2.5	1.6	2.2	1.4	1.4	1.7	4.3
18	1.2	5.0	5.0	1.1	4.1	1.9	1.5	2.2	1.4	1.5	1.7	5.2
19	10	3.8	3.8	.9	3.8	2.0	1.5	1.5	1.7	1.4	2.2	5.2
20	2.6	3.8	2.8	1.1	3.6	7.6	1.4	1.6	1.7	1.4	3.2	5.2
21	2.6	5.0	2.2	.9	1.9	2.2	1.5	1.5	1.7	1.5	3.2	5.2
22	2.6	3.8	1.4	.9	1.7	2.2	1.4	1.3	1.7	1.5	3.4	4.8
23	2.1	3.5	.9	1.2	1.7	1.9	1.4	1.4	1.9	1.5	2.9	4.5
24	2.6	2.6	1.7	1.2	1.7	1.6	1.4	1.4	1.5	1.5	2.2	4.5
25	2.4	5.0	1.2	1.0	1.6	1.6	1.4	1.4	1.9	1.5	2.9	4.3
26	3.4	4.8	1.5	1.4	1.4	1.7	1.4	1.4	1.6	1.4	9.0	4.1
27	2.9	3.8	3.8	1.4	1.4	1.7	1.2	1.4	1.6	1.4	2.4	4.0
28	2.6	3.2	3.5	1.4	1.5	1.7	1.5	1.4	1.2	1.5	2.5	4.1
29	2.8	.....	2.4	1.2	1.4	1.9	1.5	1.4	1.3	1.5	2.3	3.8
30	2.6	.....	2.0	1.1	1.4	1.8	1.5	1.4	1.2	1.4	2.4	4.0
31	3.4	.....	1.6	.....	1.4	.....	1.5	1.4	.....	1.4	.....	4.1

NOTE.—No record Jan. 1-13, 1913.

Monthly discharge of Kaimi Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 14-31	10	0.8	3.15	112	C.
February	12	.7	3.80	211	C.
March	14	.8	2.57	158	C.
April	4.8	.9	1.48	88.1	C.
May	26	1.2	5.37	330	C.
June	12	1.5	3.34	199	C.
July	2.4	1.2	1.56	95.9	C.
August	2.9	1.3	1.55	95.3	C.
September	4.3	1.2	1.70	101	C.
October	1.5	1.4	1.45	89.2	C.
November	9.0	1.4	2.30	137	C.
December	25	2.5	6.85	421	C.
The period	.....	.....	.....	2,040	

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KAMAKALEPO STREAM IN KAILUA VALLEY, NEAR KAILUA, OAHU.

Location.—At highway bridge on Waimanalo-Honolulu government road, and about 3½ miles from Waimanalo.

Records available.—November 12 to December 3, 1912; April 9 to December 31, 1913.

Gage.—Vertical staff bolted to left abutment of bridge, installed April 10, 1913, to replace original gage washed out December 3, 1912; new datum.

Control.—Shifting.

Discharge measurements.—Made by wading or from highway bridge.

Diversions.—None above station.

Accuracy.—Records good.

Cooperation.—Station maintained in cooperation with Kaneohe Ranch Co.

Discharge measurements of Kamakalepo Stream in Kailua Valley, near Kailua, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	1.29	1.33	Sept. 9	J. C. Dort	1.30	1.74
June 4	do	1.50	4.91	Dec. 10	G. R. White	1.60	7.35

Daily discharge, in second-feet, of Kamakalepo Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.3	1.7	2.4	2.1	2.6	0.9	0.5	3.7
2	.....	2.1	1.9	3.9	2.0	6.3	.8	.6	3.1
3	.....	1.4	17	2.4	1.9	2.2	.7	.5	4.3
4	.....	1.5	19	1.9	1.9	1.6	.7	.5	12
5	.....	1.5	2.4	1.7	1.9	1.6	.7	.5	13
6	.....	1.2	2.6	1.7	1.6	1.6	.7	.5	19
7	.....	1.5	2.8	1.6	1.9	1.4	.8	.5	26
8	.....	12	2.5	1.6	1.6	1.6	.7	1.4	13
9	1.6	16	3.1	1.9	1.4	1.5	.6	1.1	7.8
10	1.4	6.1	3.3	1.6	1.5	1.5	.8	.6	5.4
11	1.5	2.2	3.1	1.5	1.6	1.4	.9	.7	3.3
12	2.1	36	3.1	1.6	2.4	1.4	.7	.7	2.8
13	4.5	18	3.1	1.6	1.9	1.4	.7	.7	2.4
14	1.5	18	2.9	1.9	1.3	1.6	.6	.7	1.9
15	1.7	16	2.9	2.1	1.4	1.6	.6	.8	1.3
16	2.2	2.4	3.3	1.7	1.6	1.4	.6	.9	1.2
17	2.1	4.3	2.9	1.7	2.2	1.3	.6	.9	2.1
18	2.0	3.3	2.8	1.9	2.4	1.2	.6	1.2	2.9
19	1.6	3.3	2.9	2.1	1.6	1.6	.6	1.2	2.6
20	1.7	2.9	9.5	1.6	1.6	1.6	.6	2.0	2.4
21	1.4	2.8	3.1	1.6	1.6	1.4	.6	1.2	2.4
22	1.4	2.6	2.6	1.5	1.5	1.5	.6	1.2	2.2
23	1.7	2.8	2.5	1.4	1.5	1.7	.7	1.2	2.1
24	1.6	2.6	2.6	1.3	1.6	1.3	.8	1.6	2.1
25	1.7	2.5	2.4	1.4	1.4	1.6	.9	4.1	1.9
26	1.5	2.2	2.5	1.4	1.6	1.5	.6	8.9	1.6
27	1.5	1.9	2.4	1.4	1.6	1.4	.6	4.5	1.6
28	1.5	2.0	2.4	1.5	1.4	1.0	.6	3.7	1.6
29	1.5	2.0	2.5	1.5	1.6	1.1	.6	2.4	1.5
30	1.4	2.0	2.4	1.5	1.4	1.1	.6	3.3	1.5
31	.....	1.9	.....	1.6	1.4	.....	.6	.....	1.6

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Monthly discharge of Kamakalepo Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
April 9-30	4.5	1.4	1.78	77.6	B.
May	26	1.2	5.69	350	B.
June	19	1.7	3.94	234	B.
July	3.9	1.3	1.76	108	B.
August	2.4	1.3	1.69	104	B.
September	6.3	1.0	1.67	99.4	B.
October	.9	.6	.68	41.8	B.
November	8.9	.5	1.62	96.4	B.
December	26	1.2	4.85	298	B.
The period				1,410	

POHAKEA STREAM IN KAILUA VALLEY, NEAR KAILUA, OAHU.

Location.—One-half mile above highway bridge on the Waimanalo road.

Records available.—November 12, 1912, to December 31, 1913.

Gage.—Vertical staff, read twice daily; datum changed November 24, when 1-foot sharp-crested weir was established. Gage heights from November 25 to December 31 show head on crest of weir.

Control.—Fairly permanent.

Discharge measurements.—Made by wading with current-meter until November 24, after which low-water discharge was measured by sharp-crested weir (1-foot crest) with end contractions.

Diversions.—None above station; two small ditches below.

Accuracy.—Records poor.

Cooperation.—Maintained in cooperation with the Kaneohe Ranch Co.

Discharge measurements of Pohakea Stream in Kailua Valley, near Kailua, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	1.20	0.24	Sept. 9	J. C. Dort	1.16	0.22
June 4	do	1.68	1.50				

Daily discharge, in second-feet, of Pohakea Stream in Kailua Valley, near Kailua, Oahu, for 1912-13.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1912.			1912.			1012.		
1		1.34	11		0.33	21	0.19	0.25
2		.24	12	0.08	.28	22	.17	.24
3		1.51	13	.08	.33	23	.14	.23
4		.90	14	.06	.28	24	.11	.23
5		.82	15	.12	.25	25	.11	.23
6		.49	16	.08	.25	26	.10	.23
7		.49	17	.08	.25	27	.10	.20
8		.42	18	.06	.24	28	.11	.20
9		.37	19	.07	.24	29	.23	.20
10		.34	20	.07	.23	30	.13	.20
						31		.20

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Daily discharge, in second-feet, of Pohakea Stream in Kailua Valley, near Kailua, Oahu, for 1912–13—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	.....	0.13	0.24	0.29	0.20	0.28	0.28	0.20	0.28	0.19	0.15	0.44
2	.....	.13	.25	.33	.23	.29	.29	.19	.45	.17	.15	.39
3	.....	.12	.24	.34	.22	1.72	.23	.17	.20	.17	.15	.72
4	.....	.11	.25	.33	.20	2.02	.23	.20	.19	.17	.14	.66
5	.....	.15	.23	.38	.20	.74	.23	.20	.20	.17	.12	.72
6	.....	.90	.20	.45	.20	.31	.22	.18	.20	.17	.12	.66
7	.....	.98	.15	.38	.19	.52	.23	.18	.22	.17	.15	.66
8	.....	.44	.14	.33	.23	.42	.23	.19	.22	.17	.25	.84
9	.....	.29	.16	.28	2.02	.35	.23	.19	.20	.17	.22	.91
10	.....	.22	.19	.28	1.44	.40	.22	.19	.20	.17	.16	1.11
11	.....	.15	.17	.22	.35	.42	.22	.17	.19	.17	.15	1.04
12	.....	.17	.15	.25	1.72	.42	.20	.28	.19	.17	.15	.94
13	.....	.15	.11	.42	1.07	.42	.20	.19	.19	.17	.15	.91
14	0.16	.16	.11	.22	.98	.42	.22	.18	.20	.16	.14	.78
15	.16	.17	.11	.23	1.11	.42	.22	.17	.20	.15	.14	.63
16	.64	1.20	.11	.30	.45	.37	.20	.22	.19	.15	.14	.57
17	.22	1.72	1.54	.20	.59	.35	.20	.23	.18	.15	.14	.49
18	.20	1.54	.71	.23	.45	.31	.20	.25	.19	.15	.15	.44
19	.22	1.30	.49	.22	.38	.33	.20	.19	.22	.14	.19	.44
20	.22	1.04	.38	.23	.40	.50	.19	.19	.22	.14	.28	.44
21	.23	.90	.35	.23	.34	.38	.20	.21	.22	.15	.23	.39
22	.25	.76	.28	.22	.28	.31	.19	.17	.21	.15	.28	.39
23	.20	.49	.24	.22	.28	.30	.20	.19	.22	.16	.23	.39
24	.20	.35	.38	.22	.25	.31	.17	.17	.20	.17	.22	.34
25	.17	.52	.33	.24	.25	.33	.19	.17	.19	.16	.47	.30
26	.20	.35	.44	.22	.23	.30	.19	.17	.19	.15	.66	.32
27	.15	.33	1.54	.22	.23	.27	.20	.20	.19	.15	.49	.30
28	.11	.29	1.40	.22	.23	.27	.21	.20	.19	.16	.39	.30
29	.13	.....	.87	.22	.23	.28	.19	.20	.19	.17	.30	.30
30	.12	.....	.54	.20	.23	.28	.19	.20	.17	.16	.37	.28
31	.20	.....	.34	.....	.29	.....	.19	.20	.....	.15	.....	.25

NOTE.—No record Jan. 1-13, 1913.

Monthly discharge of Pohakea Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 14-31	0.64	0.11	0.21	7.49	C.
February	1.72	.11	.54	30.0	C.
March	1.54	.11	.41	25.2	C.
April	.45	.20	.27	16.1	C.
May	2.02	.19	.50	30.7	C.
June	2.02	.27	.47	28.0	C.
July	.29	.19	.21	12.9	C.
August	.28	.17	.19	11.7	C.
September	.45	.17	.21	12.5	C.
October	.19	.14	.16	9.84	C.
November	.66	.12	.23	13.7	C.
December	1.11	.25	.56	34.4	C.
The period	.....	.....	.....	233	

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SOUTH BRANCH OF KAHANAIKI STREAM IN KAILUA VALLEY, NEAR KAILUA, OAHU.

Location.—About 300 feet above junction of two main branches, 600 feet above bridge on government road, and 4 miles northwest (by road) from Waimanalo.
Records available.—April 10 to December 31, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made by wading.
Diversions.—None above station; small ditch 100 feet below station.
Accuracy.—Records poor.
Cooperation.—Station maintained in cooperation with the Kaneohe Ranch Co.

Discharge measurements of South Branch of Kahanaiki Stream in Kailua Valley, near Kailua, Oahu, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	0.47	0.19	Sept. 9	G. K. Larrison	0.34	0.20
June 4	do	.84	1.79				

Monthly discharge of South Branch of Kahanaiki Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
April 10-30	0.6	0.3	0.41	17.0	D.
May	4.4	.2	1.01	62.1	D.
June	3.4	.2	.70	41.7	D.
July	.5	.2	.27	16.6	D.
August	1.1	.2	.54	33.2	D.
September	2.0	.1	.32	19.0	D.
October	.1	.05	.07	4.3	D.
November	1.2	.05	.30	17.9	D.
December	4.3	.2	.88	54.1	D.
The period				266	

NORTH BRANCH OF KAHANAIKI STREAM IN KAILUA VALLEY, NEAR KAILUA, OAHU.

Location.—About 400 feet above junction of two main branches, 700 feet above bridge on government road, and 4 miles northwest of Waimanalo.
Records available.—April 11 to December 31, 1913.
Gage.—Vertical staff up to November 25; November 26 to December 31, 1913, head read on weir crest.
Control.—Probably permanent.
Diversions.—Small ditch diverts about 0.3 second-foot at point about 400 feet above station, to left.
Discharge measurements.—Made by current-meter until November 25; November 25 to December 31 by 1.0-foot sharp-crested weir.
Accuracy.—Records poor until November 25; November 26 to December 31, good.
Cooperation.—Station maintained in cooperation with the Kaneohe Ranch Co.

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Discharge measurements of North Branch of Kahanaiki Stream in Kailua Valley, near Kailua, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Apr. 11	G. K. Larrison	0.95	0.11	Sept. 9	J. C. Dort	1.05	0.54
June 4	do	1.28	2.76				

Monthly discharge of North Branch of Kahanaiki Stream in Kailua Valley, near Kailua, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
April 9-30	0.40	0.01	0.17	7.42	C.
May	3.00	.05	.49	30.1	C.
June	8.20	.10	1.04	61.9	C.
July	.30	.03	.17	10.5	C.
August	.20	.04	.06	3.69	C.
September	1.50	.05	.43	25.6	C.
October	.15	.07	.09	5.53	C.
November	.75	.07	.24	14.3	C.
December	2.20	.45	1.07	65.8	B.
The period				225	

NOTE.—Apr. 9 to Aug. 31, Sept. 3-4, and Sept. 24 to Nov. 7, the Kahanaiki ditch diverted about 0.3 second-foot from the stream above the station. Water overflowed weir Dec. 10-18; discharge estimated.

WAIAHOLE STREAM AT MANIANIAULA, NEAR WAIKANE, OAHU.

Location.—In upper Waiahole Valley, at boundary line of government and private land, 3½ miles southwest of Waikane.

Records available.—September 25, 1911, to December 31, 1913.

Gage.—Vertical staff; read twice daily.

Control.—Probably shifting.

Discharge measurements.—Made by wading.

Diversions.—None above gage.

Regulation.—Flow regulated by large springs at head of Waiahole Valley.

Accuracy.—Records good.

Discharge measurements of Waiahole Stream at Manianiaula, near Waikane, Oahu, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Mar. 1	J. C. Dort	0.96	23.4	Aug. 15	G. K. Larrison	1.29	37.2
May 3	do	.96	20.4	Sept. 12	G. R. White	1.39	43.0
June 30	G. K. Larrison	.99	22.3	Oct. 1	do	1.30	40.1
Aug. 8	J. C. Dort	1.26	37.6	Dec. 9	J. C. Dort	1.30	39.5

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Daily discharge, in second-feet, of Waiahole Stream at Manianiaula, near Waikane, Oahu, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	18	19	20	20	20	21	22	26	47	44	37	37
2	18	20	20	20	20	21	23	32	49	44	37	37
3	18	20	20	20	20	30	22	34	49	44	37	38
4	18	20	20	20	20	27	22	35	47	44	37	37
5	18	20	20	20	20	22	22	35	46	44	37	37
6	18	28	20	20	20	22	22	35	46	44	37	37
7	18	22	20	20	20	22	22	37	46	43	37	37
8	18	22	20	19	20	22	22	37	46	42	38	38
9	18	22	20	19	20	22	21	37	46	41	37	39
10	18	21	20	19	21	22	21	37	45	40	37	39
11	18	21	20	19	20	22	21	38	44	39	37	39
12	18	20	20	20	22	22	21	39	44	39	37	39
13	18	20	20	21	22	24	21	38	44	39	37	39
14	18	20	20	21	46	22	21	39	44	39	37	39
15	18	21	20	21	23	22	21	38	44	39	37	39
16	19	21	20	20	22	22	21	41	45	39	37	39
17	19	21	20	20	22	22	22	91	45	39	37	38
18	19	21	20	20	21	22	22	41	45	39	38	38
19	100	21	20	20	21	22	22	43	49	39	38	38
20	22	21	20	20	21	22	22	43	47	38	38	38
21	22	21	20	20	21	22	22	43	47	38	38	38
22	22	21	20	20	21	22	21	44	47	38	38	38
23	19	21	20	20	21	22	21	45	46	39	37	38
24	19	21	21	20	20	22	21	46	45	38	37	38
25	19	21	21	20	20	22	22	47	45	38	37	38
26	19	21	21	20	20	22	22	47	45	38	37	38
27	19	21	21	20	21	22	22	47	45	37	37	38
28	19	21	21	20	21	22	22	47	45	37	37	38
29	19	.....	20	20	21	22	22	47	45	37	37	38
30	19	.....	20	20	21	22	22	47	45	37	37	38
31	19	.....	20	.....	21	.....	22	47	.....	37	.....	38

NOTE.—Beginning Aug. 1, water developed in the Waiahole Tunnel was wasted into this stream.

Monthly discharge of Waiahole Stream at Manianiaula, near Waikane, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	100	18	21.4	1,320	A.
February	28	19	21.0	1,170	A.
March	21	20	20.2	1,240	A.
April	20	19	20.0	1,190	A.
May	46	20	21.6	1,330	A.
June	30	21	22.4	1,330	A.
July	23	21	21.7	1,330	A.
August	91	26	42.0	2,580	A.
September	49	44	45.8	2,730	A.
October	44	37	39.8	2,450	A.
November	38	37	37.2	2,210	A.
December	39	37	38.1	2,340	A.
The year	100	18	29.3	21,200	

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RIGHT BRANCH OF NORTH FORK OF KAUKONAHUA STREAM NEAR WAHIAWA, OAHU.

Location.—About 8 miles northeast of Wahiawa. and 200 feet up the Right Branch from the intake of the Waialua Agricultural Co. tunnel, which is at the confluence of the Right and Left Branches or two main branches of the North Fork.

Records available.—May 29 to December 31, 1913.

Gage.—Stevens continuous water-stage recorder.

Control.—Probably permanent.

Discharge measurements.—Made by wading or from a footbridge about 20 feet above gage.

Diversions.—None above station.

Accuracy.—Records fair.

Cooperation.—The Waialua Agricultural Co. appropriated sufficient funds to cover cost of equipment and installation of station.

Discharge measurements of Right Branch of North Fork of Kaukonahua Stream, near Wahiawa, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
May 30	J. C. Dort	2.00	10.8	Oct. 1	G. R. White	1.30	0.54
30	.....do	1.78	5.76	31	J. C. Dort	1.35	.98
July 11	.....do	1.57	2.89	Nov. 11	.....do	3.44	120
Aug. 21	G. K. Larrison	1.55	2.79	20	G. R. White	2.49	34.7
Sept. 1	J. C. Dort	3.18	92.8	26	J. C. Dort	3.88	190

Daily discharge, in second-feet, of Right Branch of North Fork of Kaukonahua Stream, near Waihiawa, Oahu, for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	4.0	11	1.4	6.2	0.8	1.1	8.5
2	.....	3.7	36	1.3	3.8	.8	3.7	7.4
3	.....	4.2	27	1.3	3.2	.8	3.3	40
4	.....	30	10	1.2	2.2	.8	1.6	55
5	.....	6.8	86	1.2	2.1	.8	1.4	21
6	.....	5.0	9.1	1.2	2.0	.8	1.4	43
7	.....	4.8	7.4	1.2	1.8	.8	4.5	27
8	.....	4.7	6.8	1.2	1.6	.7	15	14
9	.....	4.5	5.4	1.4	1.6	.6	34	11
10	.....	4.0	4.2	3.8	1.6	.6	45	9.1
11	.....	3.5	3.1	1.8	1.4	1.1	87	8.0
12	.....	3.6	2.9	67	1.4	28	114	7.4
13	.....	4.7	2.9	2.5	1.4	9.6	72	6.8
14	.....	10	2.8	2.1	1.5	2.7	20	5.7
15	.....	25	3.1	1.7	2.2	1.7	14	5.4
16	.....	5.9	2.3	2.8	2.1	1.3	9.9	5.0
17	.....	9.9	2.2	8.3	1.6	1.2	8.1	5.2
18	.....	5.9	2.3	3.2	1.6	1.0	7.2	5.6
19	.....	4.8	2.4	2.2	4.1	1.0	16	5.0
20	.....	4.0	2.0	2.0	1.8	1.3	104	3.9
21	.....	6.8	1.9	2.9	1.6	2.8	56	3.8
22	.....	9.1	1.7	2.5	1.9	3.7	20	3.6
23	.....	35	1.8	2.2	.7	2.8	15	3.1
24	.....	9.1	1.8	2.5	.7	1.8	16	2.7
25	.....	6.3	2.0	1.7	.7	3.2	80	2.5
26	.....	5.2	2.3	1.4	.7	3.6	79	2.5
27	.....	4.9	4.0	1.4	.8	1.6	46	2.4
28	.....	5.0	2.8	3.2	.8	1.3	32	2.3
29	9.6	10	2.6	3.3	.8	1.2	20	2.2
30	8.1	15	3.3	2.1	.8	1.0	16	2.2
31	4.4	.....	1.8	4.4	.....	1.0	.....	1.9

NOTE.—No records June 21–July 10, Sept. 24–30, and Dec. 1–30; discharge estimated by comparison with records of station on Left Branch of North Fork of the Kaukonahua.

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Monthly discharge of Right Branch of North Fork of Kaukonahua Stream near Wahiawa, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May 29-31	9.6	4.4	7.37	43.8	
June	35	3.5	8.51	506	C.
July	86	1.7	8.22	504	C.
August	67	1.2	4.40	271	B.
September	6.2	.7	1.82	108	B.
October	28	.6	2.59	159	B.
November	141	1.1	32.3	1,920	A.
December	55	1.9	10.4	640	C.
The period				4,150	

NOTE.—Actual maximum, Nov. 20, 10 p. m., 600 second-feet., actual minimum, Sept. 27, 29, and Oct. 11, 0.6 second-feet.

LEFT BRANCH OF NORTH FORK OF KAUKONAHUA STREAM NEAR WAHIAWA, OAHU.

Location.—About 8 miles east by north of Wahiawa and 100 feet above the intake of the Waialua Agricultural Co 's tunnel, which is at the confluence of the right and left branches or the two main branches of the North Fork.

Records available.—May 25 to December 31, 1913.

Gage.—Stevens continuous water-stage recorder.

Control.—Probably permanent.

Diversions.—None above station.

Discharge measurements.—Made by wading or from cable.

Accuracy.—Records good.

Cooperation.—The Waialua Agricultural Co. appropriated sufficient funds to cover the cost of equipment and installation of station.

Discharge measurements of Left Branch of North Fork of Kaukonahua Stream near Wahiawa, Oahu, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec. ft.*			*Feet.*	*Sec. ft.*
May 23	J. C. Dort	1.39	6.31	Sept. 1	J. C. Dort	2.08	41.6
24	do	1.62	14.9	1	do	2.52	94.6
24	do	1.78	20.5	Oct. 1	G. R. White	1.08	.93
27	do	1.40	7.26	31	J. C. Dort	1.00	.99
July 11	do	1.39	6.01	Nov. 20	G. R. White	2.70	94.1
Aug. 31	do	1.60	12.1	20	do	2.27	60.2
Sept. 1	do	1.25	2.95	26	J. C. Dort	3.00	167

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Daily discharge, in second-feet, of Left Branch of North Fork of Kaukonahua Stream near Wahiawa, Oahu, for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	4.6	20	3.6	13	1.3	0.9	15
2	.....	4.2	63	3.3	6.9	1.3	14	13
3	.....	4.8	47	3.1	7.7	1.1	1.4	70
4	.....	26	18	3.0	5.1	1.1	1.4	96
5	.....	7.7	15	2.8	4.2	1.1	1.4	37
6	.....	10	16	3.0	4.1	1.1	1.4	75
7	.....	9.1	13	3.0	3.3	1.1	1.4	47
8	.....	7.2	12	2.8	3.0	21	1.2	24
9	.....	6.2	9.4	3.8	2.8	33	1.0	19
10	.....	5.9	7.4	12	2.8	7.2	1.0	16
11	.....	7.4	6.4	4.1	2.7	4.1	1.9	14
12	.....	6.9	6.2	40	2.8	3.3	49	13
13	.....	6.2	5.9	7.2	2.5	2.7	17	12
14	.....	11	5.7	8.3	2.7	2.3	4.7	10
15	.....	21	5.7	5.7	3.4	2.3	3.0	9.4
16	.....	12	5.5	7.2	2.7	2.8	2.3	8.8
17	.....	30	4.4	20	2.3	8.3	2.1	9.1
18	.....	15	4.4	8.3	2.2	5.1	1.7	9.8
19	.....	9.1	4.4	6.2	11	3.6	1.7	8.8
20	.....	9.4	4.2	4.8	3.4	3.8	2.3	6.9
21	.....	12	4.1	11	2.4	9.8	4.9	6.6
22	.....	16	3.4	5.9	2.3	3.9	6.5	6.4
23	.....	61	3.4	5.3	3.9	2.8	4.9	5.5
24	.....	16	3.6	5.3	1.5	2.7	3.2	4.8
25	5.7	11	6.9	4.2	1.5	6.6	5.6	4.4
26	5.5	9.1	9.8	3.9	1.3	2.8	137	4.4
27	5.5	8.6	13	3.8	1.2	2.3	46	4.2
28	5.3	8.8	17	4.1	1.3	1.9	28	4.1
29	4.4	18	12	3.4	1.2	1.8	20	3.8
30	7.2	27	6.2	2.8	1.3	1.5	20	3.8
31	5.3	.....	4.4	8.3	.....	1.6	.....	3.4

NOTE.—Discharge Nov. 3-25 estimated by comparison with records of the station on the Right Branch of the North Fork of the Kaukonahua.

Monthly discharge of Left Branch of North Fork of Kaukonahua Stream near Wahiawa, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May 24-31	7.2	4.4	5.56	77.1	
June	61	4.2	13.4	797	A.
July	63	3.4	11.5	707	A.
August	40	2.8	6.78	417	A.
September	13	1.2	3.54	211	B.
October	33	1.1	4.69	288	B.
November	137	.9	12.9	768	C.
December	96	3.4	18.2	1,120	A.
The period	.....	.....	.....	4,390	

NOTE.—Actual maximum for year, Nov. 20, 10 p. m., 750 second-feet; actual minimum for year, Nov. 1, 0.9 second-feet.

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SOUTH FORK OF KAUKONAHUA STREAM NEAR WAHIAWA, OAHU.

Location.—About 10 miles east of Wahiawa by main road to United States Army reservoir and trail up ditch bank to about one-eighth mile above the United States Army ditch intake.

Records available.—June 18 to December 31, 1913.

Gage.—Stevens continuous water-stage recorder.

Control.—Probably permanent.

Discharge measurements.—Made by wading or from cable just above gage house.

Diversions.—None above station. Small ditch diverts water one-eighth mile below station for the supply of Schofield Barracks.

Accuracy.—Records fair.

Cooperation.—The Quartermaster Department, United States Army, appropriated sufficient funds to cover the cost of equipment and installation of this station.

Discharge measurements of South Fork of Kaukonahua Stream near Wahiawa, Oahu, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 18	J. C. Dort	1.66	4.27	Oct. 9	J. C. Dort	1.55	3.08
July 9	do	1.63	5.42	Nov. 11	G. R. White	2.21	30.2
Sept. 13	G. R. White	1.47	1.41	Nov. 21	do	2.00	29.6
Sept. 24	J. C. Dort	1.46	1.14	Dec. 17	do	1.58	6.66

Daily discharge, in second-feet, of South Fork of Kaukonahua Stream near Wahiawa, Oahu, for 1913.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	27	1.1	2.0	1.2	0.6	63	16	.....	4.8	3.8	2.0	1.2	7.7	7.8
2	.....	43	.9	2.0	.8	.7	57	17	.....	4.5	3.8	4.8	1.1	7.0	6.7
3	.....	28	.7	2.0	.8	9.6	51	18	.....	4.3	4.0	16	1.2	7.4	5.9
4	.....	11	.7	2.0	.7	2.2	45	19	.....	4.0	4.3	4.5	1.1	14	5.2
5	.....	15	.7	2.0	.7	1.1	39	20	23	3.8	4.5	3.2	.7	111	4.9
6	.....	11	.8	2.0	.9	1.0	33	21	9.6	3.2	2.2	2.5	.7	43	4.9
7	.....	7.7	1.2	2.0	2.2	1.1	30	22	7.0	3.0	3.0	7.4	.7	9.8	4.3
8	.....	8.0	1.2	2.0	18	13	26	23	6.1	2.7	12	3.8	.7	41	4.0
9	.....	5.8	.9	2.0	6.4	88	22	24	5.4	2.5	2.2	1.8	1.1	119	4.0
10	.....	5.1	1.8	2.2	2.0	37	20	25	5.4	5.4	1.8	2.2	4.8	29	3.8
11	.....	4.8	2.2	2.5	1.4	28	17	26	5.1	4.3	2.0	1.2	1.1	92	3.6
12	.....	4.8	35	3.0	1.1	66	15	27	11	7.4	2.2	1.0	.8	86	3.3
13	.....	4.8	7.7	2.0	2.0	35	13	28	17	12	1.4	.9	.8	80	3.1
14	.....	4.8	3.0	1.8	3.5	13	11	29	7.4	6.4	2.7	.9	1.2	74	2.9
15	.....	4.8	3.2	2.7	1.6	8.8	9.4	30	9.6	2.7	2.2	1.0	.7	68	2.7
								31	.....	2.0	2.0	.....	.7	.....	2.5

NOTE.—Discharge estimated Nov. 27 to Dec. 5, and Dec. 18.

Monthly discharge of South Fork of Kaukonahua Stream near Wahiawa, Oahu, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
June 20-30	23	5.1	9.69	211	B.
July	43	2.0	8.34	513	B.
August	35	.7	3.72	229	B.
September	16	.9	2.85	170	B.
October	18	.7	2.00	123	B.
November	119	.6	36.5	2,170	C.
December	63	2.5	16.8	1,030	C.
The period				4,450	

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MISCELLANEOUS MEASUREMENTS.

Measurements of streams on the island of Oahu at points other than regular gaging stations are listed below:

Miscellaneous discharge measurements on Oahu in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.
			Feet.	*Sec.-ft.*
Mar. 27	Waialua artesian well, in flume	Waialua		0.79
Do	Waialua artesian well, ditch	do		1.29
Do	Hauula artesian well	Hauula		1.02
Mar. 28	Lung Do Y artesian well	Honolulu		1.28
Apr. 4	Drain from Young Hotel artesian well	do		.60
Do	Alakea Street flood sewer	Alakea and Merchant Streets, Honolulu.		.75
Do	do	Alakea and Queen Streets, Honolulu.		.59
Do	do	Opposite Hawaii Electric Co. plant, Honolulu.		4.25
Do	do	100 feet above outlet, Honolulu		5.36
Apr. 11	Main Kahanaiki	Kailua Valley	0.92	1.00
Do	Kahanaiki ditch [a]	do	.82	.31
Do	Wong Leong's ditch [b]	do	1.92	4.66
May 15	Paumalu Gulch	Three-fourths mile below intake, Pupukea.		.13
Do	do	Above intake, Pupukea		.11
Do	Paumalu Stream	Below Pupukeapipe, Pupukea		.08
May 30	Waiomao Stream	Above outlet of Kaau Crater		.05
Do	do	300 feet below outlet, Kaau Crater.		.27
Do	do	Top of lower falls		.29
Do	do	900 feet elevation		.41
June 2	Kalihi Stream	Upper Kalihi Valley		2.36
June 3	Artesian well, on Bishop estate land	Below Kamehameha School		1.88
June 4	Kahanaiki ditch [a]	Kailua Valley	.60	.27
July 1	Branch Kahana Stream	Weir No. 12 Kahana Valley		.74
Do	Main Branch Kahana Stream	Weir No. 5 Kahana Valley		5.91
Do	Branch Kahana Stream	Weir No. 2 Kahana Valley		.35
July 2	Waihee Stream [c]	Upper Waiahole Valley		3.74
Do	Waianu Stream [c]	Weir No. 2 Waianu Valley		3.72
Do	Uwau Stream [d]	At weir, Waianu Valley		.48
Do	Waiawa Stream	Above intake, Waiawa Valley		2.80
Aug. 8	Portal of tunnel	Waiahole	1.94	25.5
Aug. 15	do	do	2.10	26.0
Sept. 9	Wong Leong's ditch [b]	Kailua Valley	1.49	4.22
Sept. 12	Portal of tunnel	Waiahole	2.20	31.7
Oct. 22	do	do	1.96	25.8
Oct. 31	do	do	2.03	22.4
Dec. 5	Keaahala Spring [e]	Kaneohe		.48
Jan. 25	Pukele Stream [f]	Below Mahoe Springs, Palolo	.62	.50
Feb. 26	do	do	.66	.54
Mar. 29	do	do	.64	.62
Apr. 13	do	do	1.58	19.2
June 24	do	do	.74	1.01
Feb. 26	Waioma Stream [f]	Above Pukele, Palolo	1.10	.42
Mar. 29	do	do	1.12	.62
Apr. 13	do	do	1.80	17.8
Feb. 1	Waiahole Stream	At Waiahole, near Waikane	1.08	28.8
Aug. 8	do	do		43.4
Apr. 2	Lulumaha Stream [g]	Near Honolulu	1.60	.51
Apr. 14	do	do	1.66	.62
May 23	do	do	1.61	.70
Sept. 12	do	do	1.49	.60
Nov. 10	do	do	1.71	1.78

[a] Diverts from Kahanaiki Stream.
[b] Diverts from Kailua Stream.
[c] Tributary to Waiahole Stream.
[d] Tributary to Waianu Stream.
[e] Tributary to Kaneohe Stream.
[f] Tributary to Palolo Stream.
[g] Tributary to Nuuanu Stream.

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ISLAND OF MAUI.

IAO STREAM NEAR WAILUKU, MAUI.

Location.—About 3 miles west of Wailuku and one-fourth mile below the forks of the stream.

Records available.—May 7, 1910, to December 31, 1913.

Gage.—Friez water-stage recorder.

Control.—Fairly permanent.

Discharge measurements.—Made by wading or from cable.

Diversions.—None above station.

Accuracy.—Records good.

Discharge measurements of Iao Stream near Wailuku, Maui, in 1913.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Mar. 17	C. T. Bailey	2.86	33.0	Dec. 4	C. T. Bailey	5.25	758
Aug. 12	Bailey and Christiansen	4.08	213				

Daily discharge, in second-feet, of Iao Stream near Wailuku, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	18	64	29	.....	59	92	22	35	18	12	54
2	.....	12	65	25	76	65	93	22	56	15	92	46
3	.....	12	65	22	.....	60	72	25	40	16	138	164
4	20	16	60	22	.....	56	54	23	28	19	66	553
5	19	54	61	.....	.....	64	118	28	26	40	35	270
6	18	85	62	.....	.....	66	58	28	26	40	25	254
7	18	131	66	.....	.....	60	44	30	30	43	54	148
8	18	141	65	.....	.....	49	31	27	30	36	341	108
9	20	47	64	.....	.....	90	31	51	26	26	530	83
10	20	39	59	.....	.....	59	31	32	30	25	173	66
11	19	33	56	.....	38	61	31	212	25	25	159	59
12	40	27	52	.....	134	105	54	170	27	11	146	52
13	145	26	51	338	124	72	42	75	27	71	108	51
14	157	26	70	308	290	100	37	64	22	30	69	89
15	124	74	108	326	177	122	34	82	22	18	55	69
16	44	65	132	216	119	92	32	183	25	13	111	54
17	32	60	54	181	159	75	32	93	60	11	104	66
18	26	244	29	122	132	67	30	65	66	11	183	93
19	.....	236	26	72	138	65	75	54	36	10	121	60
20	.....	141	26	66	94	66	78	43	30	10	111	54
21	.....	105	28	76	82	66	45	60	33	10	108	58
22	.....	76	79	71	74	78	37	45	30	10	66	56
23	.....	65	28	.....	79	82	49	42	30	9	49	58
24	.....	82	25	.....	79	76	47	34	28	9	126	44
25	.....	141	34	.....	69	83	40	27	27	9	159	49
26	.....	82	25	.....	96	79	35	34	27	10	141	54
27	.....	69	25	.....	85	254	24	27	27	10	54	51
28	.....	64	40	.....	85	155	25	44	21	8	44	55
29	.....	.....	22	.....	69	79	23	30	19	7	183	54
30	.....	.....	27	.....	65	150	22	19	19	6	64	52
31	22	.....	47	.....	60	.....	21	13	.....	6	.....	51

NOTE.—No record Jan. 1-3, 19-30; Apr. 5-12, 23-30; May 1, 3-10.

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Monthly discharge of Iao Stream near Wailuku, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 4-18, 31	157	18	46.3	1,470	B.
February	244	12	77.5	4,300	B.
March	132	22	52.1	3,200	B.
April 1-4, 13-22	338	22	134	3,720	B.
May 2, 11-31	290	38	106	4,620	B.
June	254	49	85.2	5,070	B.
July	118	21	46.3	2,850	B.
August	212	13	55.0	3,380	B.
September	66	19	30.9	1,840	B.
October	71	6	18.8	1,160	B.
November	530	12	121	7,200	B.
December	553	44	95.9	5,900	B
The period				44,700	

MANIANIA DITCH NEAR WAILUKU, MAUI.

Location.—About 2½ miles west of Wailuku and 800 feet below intake.
Records available.—October 18, 1910, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from plank footbridge above 50 feet above gage.
Accuracy.—Records fair.

Discharge measurements of Maniania ditch near Wailuku, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Mar. 17	1.07	22.8	May 1	1.56	33.2
Apr. 8	.74	15.8			

Monthly discharge of Maniania ditch near Wailuku, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	28	14	19.5	1,200	C.
February	26	5.0	13.5	750	C.
March	28	15	21.7	1,330	C.
April	31	17	24.1	1,430	C.
May	30	10	23.9	1,470	C.
June	31	22	26.6	1,580	C.
July	32	23	27.5	1,690	C.
August	32	20	26.5	1,630	C.
September	34	17	22.8	1,360	C.
The period				12,400	

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SOUTH WAIEHU STREAM NEAR WAILUKU, MAUI.

Location.—About 3 miles west of Wailuku and 300 feet above South Waiehu ditch intake.

Records available.—March 19 to December 31, 1913.

Gage.—Vertical staff.

Control.—Shifting.

Discharge measurements.—Made from footbridge or by wading.

Diversions.—One small taro ditch, carrying about 0.2 second-foot at ordinary stages, diverts water above the gage.

Accuracy.—Records for March, July, August, and October, good; for other months, poor.

Discharge measurements of South Waiehu Stream near Wailuku, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Mar. 18	0.58	4.91	June 28	0.54	3.02
Mar. 21	.76	8.01	July 31	.53	2.73

Daily discharge, in second-feet, of South Waiehu Stream near Wailuku, Maui, for 1913.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.8	3.8	3.8	2.4	3.4	3.6	6.3	5.6	7.1
2	.....	4.2	4.4	3.8	2.8	6.0	92	6.3	8.8	7.7
3	.....	3.8	3.8	4.2	3.0	7.4	6.5	7.1	58	76
4	.....	4.2	3.8	3.8	3.0	3.4	3.6	4.4	5.1	177
5	.....	3.8	3.8	3.8	3.0	4.7	3.6	5.6	4.0	185
6	.....	3.8	3.8	3.8	3.0	4.9	3.8	8.8	4.0	143
7	.....	3.8	3.8	3.8	2.8	5.4	20	4.7	76	44
8	.....	3.8	3.8	3.8	2.8	4.7	6.0	4.7	137	8.0
9	.....	3.8	3.8	3.8	3.0	5.6	3.8	4.7	58	5.6
10	.....	3.8	3.8	4.7	2.8	5.8	3.8	4.7	8.8	4.9
11	.....	30	3.8	3.8	5.1	7.7	4.7	4.7	5.1	5.1
12	.....	14	116	4.7	4.7	12	3.8	4.7	5.1	5.1
13	.....	49	128	4.7	4.2	3.4	4.4	4.7	5.1	4.2
14	.....	5.6	92	3.8	3.8	5.6	3.8	4.7	4.7	78
15	.....	17	17	3.8	3.8	5.4	3.8	4.7	4.7	10
16	.....	29	4.7	3.8	3.4	14	5.1	5.1	4.7	9.4
17	.....	58	4.2	3.8	3.0	4.9	11	4.2	4.9	9.1
18	.....	38	3.8	3.8	2.6	3.8	11	4.7	42	6.5
19	3.8	4.4	3.8	3.8	6.0	3.8	5.1	5.6	48	6.8
20	3.8	3.8	3.8	3.8	5.1	3.8	4.2	6.0	8.2	6.0
21	3.8	8.8	3.8	3.8	4.7	5.1	4.2	6.5	6.3	6.3
22	8.8	8.8	3.8	3.8	4.7	3.8	3.4	4.0	4.9	4.9
23	3.8	4.4	3.8	3.8	4.7	4.0	4.2	6.5	5.1	4.7
24	3.8	3.8	3.8	3.8	4.4	4.0	3.8	3.8	6.8	4.7
25	3.8	3.8	3.8	3.8	3.4	4.0	4.7	4.0	5.1	4.7
26	3.8	3.8	3.8	3.8	2.6	4.0	4.7	4.2	6.0	4.7
27	3.8	3.8	6.8	62	3.4	5.1	4.7	4.2	4.4	4.7
28	6.0	3.8	10	3.8	6.0	4.7	4.9	4.2	4.2	4.7
29	3.8	3.8	5.6	3.8	3.6	4.7	4.9	4.2	4.2	4.7
30	5.1	3.8	3.8	4.7	4.7	4.0	4.9	4.0	4.7	4.7
31	3.8	.....	3.8	.....	5.4	10	.....	4.0	.....	5.1

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Monthly discharge of South Waiehu Stream near Wailuku, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
March 19-31	8.8	3.8	4.45	115	A.
April	58	3.8	11.2	666	D.
May	128	3.8	15.1	928	D.
June	62	3.8	5.87	349	D.
July	6	2.4	3.80	234	A.
August	14	3.4	5.45	335	A.
September	92	3.4	8.27	492	D.
October	8.8	3.8	5.03	309	A.
November	137	4.0	18.3	1,090	D.
December	185	4.2	27.5	1,690	D.
The period				6,210	

SOUTH WAIEHU DITCH NEAR WAILUKU, MAUI.

Location.—About 1½ miles northwest of Wailuku, one-fourth mile above Waihee canal crossing, in flume 60 feet below intake.

Records available.—July 13, 1912, to December 31, 1913.

Gage.—Vertical staff.

Control.—Fairly permanent.

Diversions.—Ditch diverts all low-water flow.

Discharge measurements.—Made from 2 by 4 at gage.

Accuracy.—Records good.

Discharge measurements of South Waiehu ditch near Wailuku, Maui, in 1912-13.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1912		*Feet.*	*Sec.-ft.*	1913		*Feet.*	*Sec.-ft.*
July 13	J. B. Stewart	0.48	4.16	Mar. 15	C. T. Bailey	0.72	9.98
July 16	do	.45	3.79	Mar. 19	do	.36	2.51
Sept. 6	do	.42	3.47	Mar. 21	do	.50	4.57
Nov. 21	do	.48	4.27				

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Daily discharge, in second-feet, of South Waiehu ditch near Wailuku, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.0	3.0	3.0	2.8	2.8	2.8	3.2	2.8	2.5	3.0	3.2	4.6
2	3.0	3.0	3.0	3.0	3.2	2.8	4.6	3.3	15	3.0	5.0	5.0
3	4.6	3.0	3.0	2.8	2.8	3.0	2.6	3.6	4.6	3.5	7.3	7.5
4	3.8	3.0	3.0	3.0	2.8	2.8	2.6	2.6	2.5	3.2	3.2	13
5	3.0	3.8	3.0	2.8	2.8	2.8	2.6	3.2	2.5	2.8	2.8	10
6	3.0	17	3.0	2.8	2.8	2.8	2.6	3.0	2.6	5.9	2.8	13
7	3.0	15	4.6	2.8	2.8	2.8	2.8	3.3	9.4	3.0	5.7	9.9
8	3.0	19	3.0	2.8	2.8	2.8	2.8	3.2	3.0	3.0	10	5.3
9	3.0	3.8	3.0	2.8	2.8	2.8	2.6	3.3	2.6	2.8	9.9	3.6
10	3.0	3.0	3.0	2.8	2.8	3.3	2.6	4.3	2.6	2.8	4.6	3.2
11	3.0	3.0	3.0	12	2.8	2.8	2.8	4.1	2.9	2.8	2.9	3.3
12	3.0	3.0	3.0	9.9	6.4	3.3	3.2	7.8	2.6	2.8	3.0	3.3
13	3.0	3.0	3.0	12	7.1	3.3	3.0	2.6	2.9	2.8	3.0	2.8
14	3.0	3.0	3.0	4.3	12	2.8	3.3	3.5	2.4	3.0	3.0	8.6
15	3.0	3.0	5.7	8.9	12	2.8	3.3	3.5	2.4	2.8	3.0	6.8
16	3.0	4.6	3.8	10	3.3	2.8	3.3	9.4	3.0	3.0	3.0	6.4
17	3.0	6.8	4.6	12	4.6	2.8	3.0	3.2	4.0	2.8	3.2	6.1
18	3.0	6.8	3.8	8.4	2.8	2.8	2.6	2.6	5.3	2.8	8.1	4.3
19	3.0	12	2.8	3.2	2.8	2.8	5.0	2.6	3.3	2.9	7.3	4.4
20	3.0	4.6	2.8	2.8	2.8	2.8	3.3	2.6	2.8	3.0	5.3	4.0
21	3.0	3.0	2.8	6.4	2.8	2.8	2.8	3.3	2.8	3.2	4.1	4.1
22	3.0	3.0	6.0	6.4	2.8	2.8	2.5	2.6	2.4	2.7	3.3	3.2
23	3.0	3.0	2.8	3.2	2.8	2.8	2.5	2.7	2.7	3.2	3.3	3.0
24	3.0	3.0	2.8	2.8	2.8	2.8	3.0	2.7	2.6	2.8	4.1	3.0
25	3.0	4.6	2.8	2.8	2.8	2.8	2.8	2.7	2.9	2.8	3.3	3.0
26	3.0	3.0	2.8	2.8	2.8	2.8	2.7	2.7	2.9	2.8	4.0	3.0
27	3.0	3.0	2.8	2.8	4.0	7.3	2.8	3.0	2.8	2.8	2.9	3.0
28	3.0	3.0	4.3	2.8	6.4	2.8	3.5	3.0	2.9	2.8	2.8	3.0
29	3.0	.....	2.8	2.8	4.0	2.8	3.2	3.0	3.0	2.8	2.9	3.0
30	3.0	.....	5.7	2.8	2.8	3.3	3.3	2.7	3.0	2.7	3.0	3.0
31	3.0	.....	2.8	.....	2.8	.....	3.2	6.8	.....	2.7	.....	3.3

Monthly discharge of South Waiehu ditch near Wailuku, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	4.6	3.0	3.08	189	A.
February	19	3.0	5.32	295	A.
March	6	2.8	3.40	209	A.
April	12	2.8	4.92	293	A.
May	12	2.8	3.93	242	A.
June	7.3	2.8	3.02	180	A.
July	5	2.5	3.04	187	A.
August	9.4	2.6	3.54	218	A.
September	15	2.4	3.56	212	A.
October	5.9	2.7	3.00	184	A.
November	10	2.8	4.33	258	A.
December	13	2.8	5.15	317	A.
The year	19	2.4	3.83	2,780	

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NORTH WAIEHU STREAM NEAR WAILUKU, MAUI.

Location.—One mile above Waihee canal crossing and about 2½ miles northwest of Wailuku; 50 feet above uppermost diversion.
Records available.—July 9, 1912, to December 31, 1913.
Gage.—Vertical staff.
Control.—Probably shifting.
Discharge measurements.—Made by wading.
Diversions.—None above station.
Accuracy.—Records doubtful.
Cooperation.—Station is maintained in cooperation with Wailuku Sugar Co.

Discharge measurements of North Waiehu Stream near Wailuku, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Mar. 14	0.60	3.58	July 3	0.62	3.92
Apr. 10	.59	3.89	Aug. 14	.60	4.69

Daily discharge, in second-feet, of North Waiehu Stream near Wailuku, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.2	4.2	4.2	4.2	4.2	4.2	5.2	4.2	4.5	4.2	4.5	7.1
2	4.7	4.2	4.2	4.2	6.5	4.5	7.4	4.7	12	4.5	4.5	6.3
3	4.7	4.2	4.2	4.2	4.2	4.7	5.5	5.0	5.5	9.0	4.5	6.5
4	4.5	4.2	4.2	4.2	4.2	4.7	4.2	4.2	4.7	6.8	4.5	22
5	4.2	4.2	4.2	4.2	4.2	4.2	4.5	4.2	4.2	6.5	4.5	12
6	4.2	4.2	4.2	4.2	4.2	4.2	4.7	4.2	3.9	6.5	4.5	14
7	4.2	10	7.4	4.2	4.2	4.2	4.7	4.2	5.2	6.3	5.5	8.7
8	4.2	5.5	4.5	4.2	4.2	4.2	4.7	4.2	4.2	5.8	20	7.4
9	4.2	5.5	4.2	4.2	4.2	4.2	4.7	4.2	4.0	5.2	16	7.4
10	4.2	5.5	4.2	3.5	4.5	5.0	4.5	5.2	4.0	5.0	7.8	7.4
11	4.2	5.5	4.2	12	4.2	4.5	4.2	4.2	4.0	4.7	7.1	7.4
12	4.2	5.5	4.2	7.4	8.7	4.7	4.2	6.3	4.2	4.2	7.4	7.4
13	4.2	5.5	4.2	6.0	5.2	7.1	5.8	4.2	4.2	4.2	6.8	7.4
14	4.5	5.5	4.2	5.2	4.7	14	4.7	4.5	4.2	4.2	6.3	14
15	4.2	5.5	12	12	4.7	6.8	4.5	4.7	4.2	4.2	6.3	8.4
16	4.2	5.5	5.5	8.4	5.8	4.7	4.5	8.7	4.2	4.2	6.8	7.8
17	4.2	4.7	4.2	7.1	4.5	4.5	4.5	4.2	4.5	4.2	6.8	7.8
18	4.2	7.4	4.2	6.3	4.2	4.5	4.5	4.0	5.8	4.2	12	7.8
19	4.2	9.4	4.2	4.2	4.2	4.7	7.1	4.0	4.5	4.2	8.1	7.8
20	4.2	4.7	4.2	4.7	4.2	4.5	4.7	4.0	4.5	4.2	8.4	7.8
21	4.2	4.2	4.2	5.8	4.2	4.5	4.7	4.0	4.5	4.2	6.5	7.8
22	4.2	4.2	8.1	6.3	4.2	4.5	4.7	4.0	4.5	4.2	6.3	7.8
23	4.2	4.2	4.7	6.3	4.2	4.5	4.7	4.0	4.5	4.2	6.3	7.8
24	4.2	4.2	4.2	4.2	4.2	4.5	4.7	4.0	4.5	4.2	6.8	7.4
25	4.2	4.5	4.2	4.2	4.2	4.5	4.7	4.0	4.5	4.2	6.8	7.4
26	4.2	4.2	4.2	4.2	4.7	4.5	4.7	3.9	4.5	4.2	6.0	7.4
27	4.2	4.2	4.2	4.2	4.2	6.3	4.2	3.9	4.5	4.2	6.5	7.4
28	4.2	4.2	4.7	4.2	4.5	4.7	4.2	4.0	4.5	4.2	6.3	7.4
29	4.2	.....	4.2	4.2	4.2	4.7	4.7	3.9	4.5	4.2	6.3	7.4
30	4.2	.....	4.2	4.2	4.2	6.3	5.2	3.9	4.5	4.2	6.3	7.4
31	4.2	.....	4.2	.....	4.2	.....	5.2	10	.....	4.2	.....	7.4

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Monthly discharge of North Waiehu Stream near Wailuku, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	4.7	4.2	4.25	261	C.
February	10	4.2	5.17	287	C.
March	12	4.2	4.76	293	C.
April	12	3.5	5.41	322	C.
May	8.7	4.2	4.58	282	C.
June	14	4.2	5.10	303	C.
July	7.4	4.2	4.85	298	C.
August	10	3.9	4.60	283	C.
September	12	3.9	4.72	281	C.
October	9.0	4.2	4.79	295	C.
November	20	4.5	7.21	429	C.
December	22	6.3	8.55	526	C.
The year	22	3.5	5.33	3,860	

WAIHEE STREAM NEAR WAIHEE, MAUI.

Location.—About 300 feet above Waihee canal intake, 3 miles west of Waihee, and 7 miles northwest of Wailuku.

Records available.—April 1 to December 31, 1913.

Gage.—Barrett & Lawrence water-stage recorder.

Control.—Fairly permanent.

Discharge measurements.—Made from footbridge or by wading.

Diversions.—None above station.

Accuracy.—Records very good except discharge December 5–31, which was estimated.

Discharge measurements of Waihee Stream near Waihee, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 2	2.75	42.2	Aug. 13	3.00	66.5
June 30	3.82	260	Dec. 4	4.08	35.9
July 31	2.78	45.9			

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Daily discharge, in second-feet, of Waihee Stream near Waihee, Maui, for 1913.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	44	97	49	80	38	46	42	45	56
2	43	84	53	138	56	162	40	127	56
3	40	73	51	66	46	62	40	91	28
4	40	58	51	21	38	50	40	55	584
5	40	54	54	84	37	44	40	40	248
6	39	55	58	69	46	44	41	39	97
7	39	74	55	68	42	54	42	97	57
8	38	62	58	55	39	45	45	468	57
9	48	56	63	50	49	44	43	375	49
10	44	53	68	48	68	43	41	97	46
11	242	52	51	53	97	43	40	114	46
12	91	112	106	116	188	43	42	127	44
13	316	89	89	64	62	44	49	68	44
14	97	116	62	45	56	44	41	54	95
15	248	97	95	47	68	44	41	51	46
16	127	69	62	46	81	46	41	47	44
17	116	112	56	52	49	78	41	46	62
18	56	94	54	60	44	69	43	116	81
19	41	81	53	143	43	43	42	138	44
20	35	49	55	136	44	42	42	80	43
21	73	45	56	54	64	43	44	81	43
22	68	48	54	44	46	44	45	51	43
23	46	51	47	51	46	44	45	46	43
24	62	49	44	58	49	43	44	71	42
25	62	46	48	74	44	43	42	138	42
26	37	67	44	84	48	43	42	87	43
27	39	63	316	51	56	44	42	56	44
28	35	60	127	77	64	44	39	52	45
29	33	55	63	67	45	43	39	53	45
30	49	44	255	74	51	42	38	53	46
31	.....	46	.....	44	53	.....	38	.....	45

NOTE.—Discharge Dec. 5-31 estimated by comparison with record on Iao streaam.

Monthly discharge of Waihee Stream near Waihee, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
April	316	33	76.3	4,540	A.
May	116	44	68.1	4,190	A.
June	316	44	76.6	4,560	A.
July	143	21	68.4	4,210	A.
August	188	37	56.7	3,490	A.
September	162	42	50.8	3,020	A.
October	49	38	41.7	2,560	A.
November	468	40	98.8	5,880	A.
December	584	28	74.5	4,580	D.
The period	.....	.....	.....	37,000	

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SPRECKELS DITCH NEAR WAIHEE, MAUI.

Location.—About 2 miles west of Waihee and about 500 feet below intake.
Records available.—November 16, 1910, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made by wading.
Diversion.—Ditch is second diversion from Waihee Stream.
Accuracy.—Records fair.

Discharge measurements of Spreckels ditch near Waihee, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 5	0.11	0.51
June 30	1.80	68.9

Monthly discharge of Spreckels ditch near Waihee, Maui, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
January	14	0.0	2.24	138	B.
February	64	1.0	18.4	1,060	A.
March	58	7.2	31.4	1,930	A.
April	82	7.2	35.7	2,120	A.
May	70	1.8	13.9	855	B.
June	58	.5	9.04	538	B.
July	73	1.0	16.8	1,030	B.
August	55	.0	10.2	627	B.
September	26	1.0	2.90	173	B.
October	43	1.0	10.7	658	C.
November	67	1.6	19.1	1,140	B.
December	67	1.6	12.8	787	B.
The year	82	.0	15.2	11,100	
1913.					
January	67	1.0	9.84	605	C.
February	58	1.0	13.6	755	C.
March	64	.5	13.6	836	B.
April	67	.5	23.9	1,420	B.
May	43	1.6	11.8	726	C.
June	67	1.2	12.2	726	B.
July	67	.9	9.34	574	B.
August	51	1.4	8.78	540	B.
September	26	.5	2.73	162	B.
The period				6,340	

NOTE.—Ditch dry, Jan. 15–18, 21–24, and Aug. 27–30, 1912.

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KAHAKULOA STREAM AT KAHAKULOA, NEAR WAIHEE, MAUI.

Location—About 13 miles northwest of Wailuku at trail bridge of Kahakuloa, below all diversions.
Records available.—August 27, 1912, to March 31, 1913.
Gage.—Staff gage on left bank, just below trail bridge.
Control.—Probably permanent.
Discharge measurements.—Made by wading.
Accuracy.—Records good.

Station discontinued March 31, 1913, and record continued at new station 3 miles above mouth of stream by water-stage recorder.

Daily discharge, in second-feet, of Kahakuloa Stream at Kahakuloa, near Waihee, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.
1	6	3	5	11	5	3	5	21	3	8	5
2	6	3	5	12	5	3	5	22	5	6	25
3	10	3	5	13	21	3	5	33	5	6	7
4	6	3	5	14	18	3	5	24	5	6	5
5	5	3	5	15	10	4	20	25	5	18	10
6	5	137	5	16	8	10	9	26	5	7	5
7	5	36	18	17	6	6	11	27	5	5	5
8	5	26	8	18	4	83	5	28	3	5	9
9	5	6	10	19	3	39	5	29	3	.....	6
10	5	5	5	20	3	10	5	30	3	.....	5
								31	3	.....	5

Monthly discharge of Kahakuloa Stream at Kahakuloa, near Waihee, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	21	3	6.0	369	A.
February	137	3	16.1	894	B.
March	25	5	7.5	461	A.

KAHAKULOA STREAM NEAR HONOKAHAU, MAUI.

Location.—About 12 miles southeast of Honokahau and 3 miles above mouth of stream.
Records available.—January 22 to August 31, 1913.
Gage.—Stevens water-stage recorder.
Control.—Fairly permanent.
Discharge measurements.—Made from footbridge or by wading.
Diversions.—None above station.
Accuracy.—Records for January, June, and July, good; for other months, poor.

Discharge measurements of Kahakuloa Stream near Honokahau, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 23	1.00	1.65	May 21	1.10	2.46
Mar. 9	1.17	3.57	Oct. 5	1.10	2.65

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Daily discharge, in second-feet, of Kahakuloa Stream near Honokahau, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	.....	2.4	2.0	.....	3.2	4.0	11	3.0
2	.....	2.0	2.0	.....	3.7	3.6	19	11
3	.....	1.6	1.9	.....	3.2	11	4.7	3.6
4	.....	1.6	2.0	.....	2.8	9.5	3.6	3.0
5	.....	8.2	1.8	.....	2.6	4.4	10	3.4
6	.....	38	1.8	.....	2.5	5.1	5.3	3.8
7	.....	2.2	7.2	.....	8.5	5.8	3.2	3.7
8	.....	2.6	3.0	1.7	5.3	5.3	3.1	8.5
9	.....	3.0	4.0	2.5	25	5.1	2.8	3.1
10	.....	3.4	2.3	2.8	8.2	7.5	3.1	8.5
11	.....	3.7	2.1	59	14	7.5	3.7	11
12	.....	4.1	2.0	34	13	5.1	13	2.2
13	.....	4.5	2.0	86	12	20	5.5	3.7
14	.....	4.9	2.3	26	11	9.8	2.8	3.1
15	.....	5.3	.....	68	9.7	4.2	2.6	2.8
16	.....	5.7	.....	35	8.5	6.9	3.0	2.8
17	.....	6.0	.....	35	7.3	4.0	3.6	2.8
18	.....	6.4	.....	8.2	6.1	3.2	3.1	2.6
19	.....	6.8	.....	8.8	4.9	3.2	5.5	2.6
20	.....	7.2	.....	6.2	3.7	2.8	2.8	.....
21	.....	3.7	.....	32	3.1	2.6	2.6	.....
22	1.6	2.5	.....	18	3.7	3.0	3.0	.....
23	1.6	2.3	.....	8.5	5.8	3.0	3.0	.....
24	1.8	2.2	.....	5.1	3.8	3.1	3.1	.....
25	2.0	8.2	.....	15	3.8	5.1	2.8	.....
26	1.9	3.1	.....	5.5	7.5	3.6	4.7	.....
27	2.0	2.2	.....	7.5	6.9	73	3.4	.....
28	1.9	2.1	.....	3.7	5.5	23	3.4	.....
29	1.6	.....	.....	3.4	7.2	9.8	3.4	.....
30	1.5	.....	.....	3.2	8.2	22	2.8	.....
31	2.0	.....	.....	.....	4.4	.....	2.8	.....

NOTE.—No record Mar. 15 to Apr. 7 and Aug. 20–31.

Monthly discharge of Kahakuloa Stream near Honokahau, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January 22–31	2.0	1.5	1.79	36	A.
February	38	1.6	5.21	289	D.
March 1–14	7.2	1.8	2.60	72	D.
April 8–30	86	1.7	20.7	944	D.
May	25	2.5	6.94	427	D
June	73	2.6	9.14	544	A.
July	19	2.6	4.73	291	A.
August 1–19	11	2.2	4.48	169	D.
The period	.....	.....	.....	2,770	

NOTE.—No record Mar. 15 to Apr. 7. Automatic gage out of order Aug. 20 to Dec. 31, 1913.

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HONOKAHAU STREAM NEAR HONOKAHAU MAUI.

Location.—On right bank, 1,000 feet above Honokahau ditch intake, about 6 miles southeast of Honokahau post office.
Records available.—March 6 to December 31, 1913.
Gage.—Stevens water-stage recorder.
Control.—Fairly permanent.
Discharge measurements.—Made from cable 400 feet below gage or by wading.
Diversions.—None above station.
Accuracy.—Records good.

Discharge measurements of Honokahau Stream near Honokahau, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Mar. 7	1.19	19.0	July 8	1.21	19.8
8	1.07	17.3	Aug. 22	1.18	19.1
May 21	1.20	20.0	Oct. 4	1.11	17.0

Daily discharge, in second-feet, of Honokahau Stream near Honokahau, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	35	73	20	71	20	.....	18	15	22
2	.....	.....	.....	21	43	20	98	23	.....	16	77	22
3	.....	.....	.....	19	46	21	36	26	.....	16	91	44
4	.....	.....	.....	17	24	22	34	20	.....	18	49	264
5	.....	.....	.....	18	21	24	52	20	.....	17	21	151
6	.....	.....	.....	17	20	28	42	30	.....	44	19	145
7	.....	.....	30	17	24	28	30	26	.....	36	30	55
8	.....	.....	18	17	25	27	24	24	.....	55	195	41
9	.....	.....	19	26	21	33	20	22	.....	19	257	35
10	.....	.....	16	19	.....	43	20	53	.....	16	99	34
11	.....	.....	16	183	.....	22	20	35	.....	16	122	34
12	.....	.....	16	155	.....	68	44	183	.....	16	129	35
13	.....	.....	15	248	.....	75	45	37	.....	49	65	35
14	.....	.....	16	106	.....	28	29	36	.....	43	28	65
15	.....	.....	53	200	.....	62	23	42	.....	22	26	46
16	.....	.....	68	125	24	28	20	58	.....	21	50	32
17	.....	.....	25	129	47	21	20	24	.....	16	57	46
18	.....	.....	19	61	.....	20	20	19	.....	16	117	83
19	.....	.....	17	30	.....	19	36	18	.....	16	123	32
20	.....	.....	17	32	24	18	54	18	.....	16	42	28
21	.....	.....	26	62	22	19	25	22	17	15	89	29
22	.....	.....	90	44	20	20	24	22	17	15	36	27
23	.....	.....	20	61	24	22	26	20	17	15	28	26
24	.....	.....	16	.....	29	21	30	26	16	15	95	26
25	.....	.....	40	.....	23	29	27	22	16	25	135	26
26	.....	.....	16	.....	45	24	25	20	16	18	113	26
27	.....	.....	18	.....	33	127	20	39	16	17	38	25
28	.....	.....	34	24	29	134	24	22	16	18	25	25
29	.....	.....	18	29	27	53	22	.....	18	16	23	25
30	.....	.....	24	22	25	106	21	.....	17	15	22	25
31	.....	.....	55	.....	21	.....	20	.....	.....	15	.....	25

NOTE.—No record Jan. 1 to Mar. 6, Apr. 24-27, May 10-15, 18-19, and Aug. 29 to Sept. 20.

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Monthly discharge of Honokahau Stream near Honokahau, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
March 7-31	90	15	28.1	1,390	B.
April 1-23, 28-30	248	17	66.1	3,400	B.
May 1-9, 16-31	73	20	30.0	1,370	B.
June	134	18	39.4	2,340	B.
July	98	20	32.3	1,990	B.
August 1-28	183	18	33.1	1,840	B.
September 23-30	18	16	16.6	329	B.
October	55	15	21.6	1,330	B.
November	257	15	73.9	4,400	B.
December	264	22	49.5	3,040	B.
The period				21,400	

HONOKAHAU DITCH AT INTAKE, NEAR HONOKAHAU, MAUI.

Location.—About 9 miles by trail above Honokahau, 350 feet below ditch intake.
Records available.—February 3, 1907, to September 6, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from plank at gage.
Diversion.—Ditch diverts total low flow of Honokahau Stream.
Accuracy.—Records good.
Cooperation.—Gage is the property of the Honolua Ranch Co.

Discharge measurements of Honokahau ditch at intake near Honokahau, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Mar. 7	1.88	20.5
July 10	1.88	19.7

Monthly discharge of Honokahau ditch at intake, near Honokahau, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	43	16	21.8	1,340	A.
February	43	16	24.1	1,340	A.
March	43	16	22.5	1,380	A.
April	43	16	30.4	1,810	A.
May	43	19	28.3	1,740	A.
June	43	19	27.9	1,660	A.
July	43	19	27.3	1,680	A.
August	43	18	24.3	1,490	A.
September 1-6	34	18	23.2	276	A.
The period				12,700	

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HONOLUA STREAM NEAR HONOKAHAU, MAUI.

Location.—About 2 miles south of Honokahau and 300 feet above Honokahau ditch crossing.

Records available.—March 12 to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably shifting.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records for low and medium stages good; flood records are little more than estimates.

Discharge measurements of Honolua Stream near Honokahau, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Mar. 12	0.53	0.74	July 10	0.55	1.45
May 20	.81	4.11	Aug. 22	.46	.78
May 22	.69	2.36			

Daily discharge, in second-feet, of Honolua Stream near Honokahau, Maui, for 1913.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.0	2.4	1.2	13	0.8	1.4	0.4	0.6	1.7
2	.....	1.2	3.7	1.2	13	.8	5.4	.4	.7	1.5
3	.....	1.1	4.0	1.4	6.0	4.6	6.0	.4	24	1.5
4	.....	.8	2.6	2.4	5.2	1.0	1.5	.8	4.4	85
5	.....	.4	1.9	1.9	4.1	.8	.8	.6	3.1	55
6	.....	.4	1.4	2.7	6.9	.8	.8	2.8	1.5	51
7	.....	.4	1.3	2.4	3.3	.8	1.0	4.6	1.2	6.9
8	.....	.4	1.6	1.6	2.4	.8	.8	6.0	40	11
9	.....	.4	1.6	2.1	1.7	.7	.7	.8	17	3.8
10	.....	.4	1.2	5.6	1.4	2.4	.8	.8	11	3.0
11	.....	37	1.2	2.2	1.4	2.1	.8	.6	9.6	3.0
12	0.8	22	26	6.5	1.6	43	.8	.6	8.2	3.0
13	.6	56	4.4	13	7.7	4.4	.8	.6	6.2	2.8
14	.5	28	14	2.4	4.1	5.4	.6	5.2	3.7	25
15	12	51	28	5.6	2.1	14	.6	1.2	3.4	8.5
16	15	37	8.3	2.6	1.5	11	.6	1.2	3.0	5.4
17	5.6	27	7.4	1.6	1.3	2.6	.6	.8	3.0	39
18	2.2	15	12	.9	1.2	2.1	2.2	.7	38	6.0
19	1.4	12	18	.7	1.0	1.5	1.4	.5	69	6.9
20	.7	9.1	5.0	.6	4.1	1.3	1.0	.5	3.8	5.2
21	1.0	16	3.2	.5	2.6	.9	.8	.4	3.0	4.3
22	27	10	2.5	.5	1.5	.8	.6	.4	2.2	4.8
23	8.7	15	2.4	.5	1.4	.8	.5	.4	1.7	3.6
24	1.1	7.2	2.6	.5	1.5	.8	.5	.3	3.6	3.3
25	2.9	31	2.6	.5	2.0	.8	.5	24	30	3.0
26	1.4	7.6	2.4	1.0	1.6	.8	.5	2.4	54	2.8
27	1.1	9.1	3.2	14	1.4	1.2	.4	.7	15	2.6
28	2.2	5.4	3.3	24	1.0	5.6	.4	.6	3.4	2.6
29	1.2	5.0	3.2	16	.8	2.1	.4	.5	1.9	2.2
30	.8	4.0	3.4	12	.8	1.1	.4	.4	1.4	2.1
31	3.2	.....	1.6	.....	.8	6.2	.....	.4	.....	2.1

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Monthly discharge of Honolua Stream near Honokahau, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
March 12-31	27	0.5	4.22	168	C.
April	56	.4	13.7	815	D.
May	28	1.2	5.69	350	B.
June	24	.5	4.27	254	B.
July	13	.8	3.17	195	B.
August	43	.7	3.94	242	B.
September	6	.4	1.12	67	B.
October	24	.3	1.94	119	B.
November	69	.6	12.2	726	C.
December	85	1.5	11.6	713	C.
The period				3,650	

HONOKAWAI STREAM NEAR LAHAINA, MAUI.

Location.—Eight miles northeast of Lahaina, 500 feet below junction of Honokawai and Amalu streams.

Records available.—May 13 to December 31, 1913.

Gage.—Vertical staff..

Control.—Probably permanent.

Discharge measurements.—Made from footbridge or by wading.

Diversions.—Most of the normal flow is diverted into Honokawai ditch half a mile above gage.

Accuracy.—Low-flow records good; flood discharges only estimates.

Discharge measurements of Honokawai Stream near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
May 16	1.23	1.06
May 23	.97	.10

Monthly discharge of Honokawai stream near Lahaina, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May 13-31	12	0.2	2.41	90.6	C.
June	9.6	.0	1.43	85.1	C.
July	12	.0	1.11	68.2	C.
August	7.0	.0	.66	40.6	C.
September	2.2	.0	.09	5.5	C.
October	10	.0	.48	29.5	C.
November	18	.0	3.76	224	C.
December	21	.0	1.65	101	C.
The period				644	

NOTE.—No discharge during periods as follows: June 1; July 9, 11, 16, 17, 24-31; Aug. 1-9, 11, 18-27, 30; Sept. 1, 2, 4-17, 19-30; Oct. 1-5, 9-12, 15-25, 27-31; Nov. 1, 2, 6, 7, 14, 15, 23, 28-30; Dec. 1-3, 12-14, 16, 19-31.

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HONOKAWAI DITCH NEAR LAHAINA, MAUI.

Location.—Two miles above Pioneer Mill Co.'s power house, and about 7 miles northeast of Lahaina; 250 feet below junction with Amalu wooden flume and 1,000 feet below intake.

Records available.—July 1, 1912, to December 31, 1913.

Gage.—A graduated rod gage, which the observer places in the center of flume each time a reading is taken.

Control.—Probably permanent.

Discharge measurements.—Made in flume near gage.

Diversion.—Ditch diverts all low-water flow from Honokawai and Amalu streams.

Accuracy.—Records good except extremely high discharges.

Cooperation.—Station maintained in cooperation with Pioneer Mill Co.

Discharge measurements of Honokawai ditch near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 18	1.20	10.5
Aug. 21	.92	5.24

Daily discharge, in second-feet, of Honokawai ditch near Lahaina, Maui, for 1912–13.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.							1912.						
1	7.9	6.7	6.5	13	7.0	8.9	16	7.5	14	6.2	6.4	22	6.5
2	7.9	6.5	18	6.8	6.5	12	17	6.5	7.9	6.2	6.4	22	6.2
3	8.6	6.5	7.2	6.7	6.2	20	18	6.5	6.7	6.2	6.2	23	5.9
4	7.5	6.5	7.5	6.5	6.0	6.7	19	6.5	6.5	6.2	6.2	11	17
5	8.6	6.5	6.8	7.2	5.9	5.9	20	12	6.5	6.4	6.0	8.7	8.2
6	9.3	6.5	6.8	6.8	6.2	5.9	21	8.2	6.5	7.2	8.6	14	17
7	6.7	7.5	14	6.2	6.2	11	22	7.0	8.6	6.8	20	8.6	22
8	17	7.5	6.7	6.8	6.4	13	23	12	6.8	6.2	10	9.1	15
9	10	13	7.4	6.5	22	6.5	24	6.8	6.5	6.2	8.4	6.8	8.7
10	7.9	16	6.5	6.5	8.9	6.0	25	6.5	6.5	6.2	6.5	6.2	6.5
11	6.7	7.9	6.5	8.9	8.2	5.9	26	6.5	13	6.2	14	6.2	17
12	11	8.2	6.2	7.5	6.5	5.9	27	6.8	9.1	6.2	15	5.9	6.7
13	7.2	7.9	6.2	7.2	6.2	5.9	28	7.2	6.7	6.7	17	6.2	12
14	6.7	8.6	6.2	12	6.2	7.2	29	6.7	9.6	9.1	6.5	5.9	7.0
15	6.5	18	6.2	9.3	6.0	7.2	30	6.7	8.2	10	11	5.8	14
							31	6.8	7.2	.....	22	.....	6.5

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Daily discharge, in second-feet, of Honokawai ditch near Lahaina, Maui, for 1912–13—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	6.8	5.3	5.0	15	12	4.9	9.5	5.0	5.3	5.3	5.0	5.8
2	6.4	5.0	5.0	6.5	8.6	4.9	8.9	5.0	5.0	5.2	5.0	5.3
3	17	5.0	5.0	5.6	10	5.6	8.0	5.0	7.9	5.3	16	5.0
4	6.2	5.0	5.0	5.3	6.5	5.0	8.6	5.0	5.6	5.4	14	11
5	5.8	4.9	4.9	5.2	6.5	5.0	8.6	5.2	5.2	5.0	5.9	6.2
6	5.8	10	4.9	5.0	5.3	6.2	8.2	7.9	5.0	7.9	5.3	7.9
7	5.8	6.2	4.9	5.0	5.0	6.5	7.5	5.3	5.0	7.7	5.2	6.5
8	8.2	17	4.9	4.9	6.2	5.8	6.2	6.8	5.3	15	18	5.0
9	8.6	5.6	4.9	6.8	5.0	6.8	5.6	5.0	5.6	6.8	18	6.5
10	10	5.0	4.9	5.0	5.0	6.8	5.3	7.9	5.3	5.0	16	6.8
11	6.5	5.2	4.9	20	6.5	5.3	5.3	5.2	5.2	5.3	16	5.9
12	5.9	5.0	4.8	22	12	7.5	7.2	23	5.9	5.0	19	5.8
13	23	5.0	4.8	22	8.0	8.6	7.5	7.4	5.3	11	13	5.6
14	23	5.0	4.8	21	8.2	6.7	7.5	10	5.0	10	6.5	5.9
15	23	6.5	10	23	3.8	6.5	6.2	9.6	5.3	6.4	6.2	6.2
16	7.7	6.2	13	22	4.8	6.2	5.4	11	6.2	5.3	8.6	5.3
17	6.2	5.3	5.9	21	6.2	5.6	5.3	8.2	9.1	5.0	14	6.8
18	6.0	22	5.6	20	7.0	5.2	5.8	5.3	12	5.0	16	14
19	6.2	17	5.0	8.2	5.0	5.0	7.9	5.0	9.1	5.0	16	8.0
20	5.8	5.9	5.0	8.4	5.8	5.0	6.2	5.0	5.3	4.9	8.6	5.9
21	5.6	5.9	12	8.6	5.3	5.0	6.2	5.0	5.0	5.0	16	5.3
22	5.6	5.3	21	6.7	5.3	5.0	7.0	5.0	5.0	5.0	7.4	5.3
23	5.6	5.0	5.6	8.6	5.4	5.4	6.5	5.0	5.0	5.0	6.2	5.0
24	5.6	5.0	5.0	9.6	7.5	5.6	6.2	5.0	5.0	5.2	12	5.0
25	5.6	12	12	8.9	7.2	6.8	5.8	5.3	4.8	9.1	16	5.0
26	5.6	5.8	5.2	7.2	5.9	5.9	5.3	5.0	4.8	8.4	16	5.3
27	5.6	5.2	5.3	9.6	5.9	11	5.0	10	4.8	5.3	12	5.0
28	5.3	5.0	11	8.2	5.9	17	5.6	11	4.8	5.0	6.2	5.0
29	5.0	.....	5.3	8.6	5.3	7.9	5.0	7.2	5.2	5.0	5.9	5.0
30	5.0	.....	8.9	6.4	5.0	9.5	5.0	5.9	5.3	5.0	5.3	5.0
31	5.4	.....	14	.....	5.0	.....	5.0	13	.....	5.0	.....	5.0

Monthly discharge of Honokawai ditch near Lahaina, Maui, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
July	17	6.5	8.05	495	B.
August	18	6.5	8.52	524	B.
September	18	6.2	7.36	438	B.
October	20	6.0	9.29	571	C.
November	23	5.8	9.19	547	C.
December	22	5.9	9.81	603	C.
The period	.....	.....	.....	3,180	
1913.					
January	23	5.0	8.19	504	B.
February	22	4.9	7.19	399	B.
March	21	4.8	7.05	433	B.
April	23	4.9	11.1	660	C.
May	12	3.8	6.49	399	A.
June	17	4.9	6.61	393	A.
July	9.5	5.0	6.56	403	A.
August	23	5.0	7.26	446	B.
September	12	4.8	5.78	344	A.
October	15	4.9	6.27	386	A.
November	19	5.0	11.2	666	C.
December	14	5.0	6.17	379	A.
The year	23	3.8	7.48	5,410	

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KAHOMA DITCH AT WEIR, NEAR LAHAINA, MAUI.

Location.—About 3½ miles east of Lahaina, at portal of the lower of two development tunnels of Pioneer Mill Co.

Records available.—August 1, 1911, to December 31, 1913.

Gage.—Staff.

Discharge measurements.—A 4-foot sharp-crested weir with end contractions; measured discharge from development tunnel and amount diverted by small pipe from stream. Measurements checked by current meter.

Accuracy.—Records very good.

Cooperation.—Records kept by Pioneer Mill Co.

Discharge measurements of Kahoma ditch at weir, near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 14	0.67	7.54
Aug. 19	.42	3.79

Daily discharge, in second-feet, of Kahoma ditch at weir, near Lahaina, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.50	2.76	2.76	6.19	5.58	3.00	6.19	3.37	3.76	3.37	3.37	3.76
2	3.24	2.76	2.88	5.58	4.71	3.00	7.97	3.37	3.50	3.37	3.37	3.76
3	4.02	2.76	2.76	4.43	4.43	3.00	7.64	3.37	4.43	3.37	6.50	3.76
4	3.37	2.64	2.76	3.12	3.63	3.00	7.80	3.37	3.50	3.37	6.19	7.47
5	3.12	2.64	2.76	3.12	3.12	3.00	7.14	3.37	3.50	3.37	4.43	6.50
6	2.88	3.89	2.76	3.00	3.12	3.89	5.88	4.71	3.37	6.82	3.76	6.19
7	2.88	7.64	2.76	3.00	3.12	3.63	5.29	5.73	3.37	5.58	3.50	4.57
8	3.89	3.89	2.76	2.88	3.12	3.63	4.71	4.16	3.37	6.19	6.82	3.89
9	7.14	2.88	2.76	5.58	3.00	4.71	3.63	3.63	3.37	4.43	7.80	3.50
10	6.35	2.88	2.76	3.37	3.00	5.58	3.50	3.50	3.37	3.63	6.82	3.50
11	4.29	2.76	2.76	7.80	3.00	3.63	3.37	3.50	3.37	3.50	6.50	3.37
12	5.29	2.76	2.76	7.80	5.43	4.71	4.99	7.80	3.63	3.50	6.98	3.37
13	7.14	2.76	2.76	7.97	4.85	6.19	5.29	5.58	3.76	5.58	5.58	3.37
14	7.14	2.64	2.76	6.82	6.66	4.43	5.29	5.58	3.63	5.73	4.71	3.37
15	7.47	5.73	4.43	8.14	6.35	5.58	4.43	5.88	3.63	3.76	4.99	3.37
16	4.43	3.00	5.43	7.80	4.43	4.43	3.63	5.43	4.16	3.76	5.88	3.37
17	3.63	2.88	5.14	7.97	3.63	3.37	3.63	4.85	5.58	3.50	6.50	3.37
18	3.12	7.64	3.89	7.14	6.04	3.37	3.50	4.02	7.80	3.50	6.50	6.50
19	3.63	6.66	3.12	5.29	5.73	3.12	5.14	3.63	5.14	3.50	6.98	4.71
20	3.12	3.37	2.88	4.99	3.63	3.12	5.58	3.76	3.76	3.50	5.14	3.89
21	3.12	3.63	6.19	5.73	3.37	3.00	3.89	3.50	3.50	3.50	5.58	3.37
22	2.88	2.88	6.82	4.57	3.37	3.00	3.63	3.50	3.37	3.50	4.57	3.37
23	2.88	2.76	3.63	5.88	3.12	3.00	4.16	3.50	3.37	3.50	4.43	3.37
24	2.88	2.76	3.12	5.29	6.19	3.00	4.71	3.37	3.50	4.71	7.80	3.37
25	2.88	5.58	5.14	6.50	3.50	4.43	3.76	4.02	3.37	5.88	7.47	3.37
26	2.88	4.16	3.12	4.29	5.88	4.99	3.50	3.50	3.37	4.43	7.14	3.37
27	2.88	4.16	4.71	5.58	3.89	5.58	3.50	3.50	3.37	3.63	6.04	3.37
28	2.88	4.16	6.19	6.19	3.37	6.98	3.50	5.58	3.37	3.50	4.43	3.24
29	2.88	.....	3.63	4.99	3.12	5.58	3.37	4.43	3.37	3.50	3.89	3.24
30	2.88	.....	4.43	3.63	3.12	6.19	3.37	4.43	3.37	3.50	3.89	3.24
31	2.88	.....	6.82	.....	3.00	.....	3.37	5.88	.....	3.50	.....	3.24

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Monthly discharge of Kahoma ditch at weir, near Lahaina, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	7.47	2.88	3.92	241	A
February	7.64	2.64	3.75	208	A
March	6.82	2.76	3.79	233	A
April	8.14	2.88	5.49	327	A
May	6.66	3.00	4.15	255	A
June	6.98	3.00	4.14	246	A
July	7.97	3.37	4.69	288	A
August	7.80	3.37	4.32	266	A
September	7.80	3.37	3.80	226	A
October	6.82	3.37	4.08	251	A
November	7.80	3.37	5.58	332	A
December	7.47	3.24	3.94	242	A
The year	8.14	2.64	4.30	3,120	

LAHAINALUNA STREAM NEAR LAHAINA, MAUI.

Location.—One-fourth mile above Lahainaluna Seminary, about 1½ miles northeast of Lahaina, and 8 feet above Pioneer Mill Co.'s upper ditch intake. Previous to May 7, 200 feet downstream from present location.

Records available.—August 1, 1911, to December 31, 1913.

Gage.—Vertical staff; datum changed May 7, 1913.

Control.—Shifting.

Discharge measurements.—Made by wading.

Diversions.—Most of the normal flow of the stream is diverted into Lahainaluna ditch about 1 mile above the gage.

Accuracy.—Records good except for flood discharges.

Cooperation.—Station maintained in cooperation with Pioneer Mill Co.

Discharge measurements of Lahainaluna Stream near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 15	1.95	125	May 12	1.18	1.73
Apr. 17	1.45	54.7	May 16	1.40	3.07
May 7[a]	1.02	1.00	Aug. 19	1.18	.96
			Sept. 30	1.15	.91

[a] Gage moved upstream 200 feet; new datum.

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Daily discharge, in second-feet, of Lahainaluna Stream near Lahaina, Maui, for 1912–13.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.												
1	2.2	1.2	1.5	7.0	1.8	1.5	2.2	1.1	2.2	3.6	2.0	2.5
2	2.3	2.5	3.6	11	3.4	1.4	1.6	1.1	14	2.8	.7	2.0
3	1.8	2.3	3.9	6.6	1.4	1.3	2.2	1.1	1.4	.9	.7	2.8
4	1.8	1.5	2.0	5.6	2.9	1.3	3.9	1.1	1.8	.5	.6	1.5
5	2.0	1.5	1.8	32	4.4	10	2.0	1.1	.7	.5	.8	1.5
6	1.6	1.4	1.6	16	5.1	1.1	1.1	1.0	16	.7	.8	.8
7	1.6	1.3	3.1	46	1.5	1.1	1.5	1.0	5.8	.7	.7	3.1
8	2.2	1.3	2.3	20	4.2	1.1	1.1	1.4	.9	1.8	1.6	1.0
9	2.0	1.3	4.6	8.8	1.5	2.5	7.6	2.5	1.0	.7	132	1.0
10	1.6	2.0	2.5	7.2	1.5	1.4	1.5	4.6	.5	.8	3.9	1.0
11	1.8	1.3	22	3.5	1.5	1.3	1.5	8.0	.5	.8	5.1	1.0
12	1.8	1.3	3.6	3.2	1.4	1.3	1.3	3.1	.5	.7	2.3	.9
13	1.6	1.3	3.1	3.1	1.3	1.3	2.2	1.0	.5	1.0	1.5	.9
14	1.6	1.2	1.5	8.0	1.3	1.5	1.4	1.0	.5	2.3	1.0	.9
15	1.6	1.2	1.5	1.8	1.3	1.8	1.2	3.5	.5	.7	1.0	1.3
16	1.6	1.2	1.5	1.6	1.3	2.0	1.1	2.0	.5	.8	3.1	1.3
17	1.6	1.2	10	1.9	1.3	1.8	1.3	1.8	.7	.7	5.6	1.3
18	1.5	1.2	6.4	1.8	1.3	1.3	1.1	.5	.7	.7	6.4	1.0
19	1.3	11	1.6	1.5	2.7	1.5	1.1	.5	.9	.7	4.2	2.5
20	1.3	46	2.7	1.5	1.5	1.8	1.0	.5	.8	.7	3.9	2.0
21	1.3	124	1.5	1.5	6.4	8.0	1.3	.5	.8	3.1	4.2	16
22	1.3	55	1.5	3.1	2.8	1.5	1.3	2.0	.8	2.8	2.5	55
23	1.3	8.0	1.3	1.6	1.8	1.6	1.3	1.0	.8	4.2	2.8	29
24	1.3	3.9	1.3	2.8	2.7	5.1	3.6	.5	.8	1.1	.9	3.4
25	1.3	3.6	1.2	8.8	1.5	1.5	1.4	.5	.9	.6	1.0	2.4
26	1.3	3.5	1.2	3.9	3.6	1.5	1.0	.9	.9	8.0	.7	14
27	1.3	100	1.0	2.0	19	1.3	2.0	.5	.9	7.0	.7	2.5
28	1.3	6.8	1.0	1.8	4.4	1.3	1.1	1.1	.9	2.5	1.4	2.0
29	1.2	1.8	1.4	1.5	1.6	1.3	1.1	1.8	1.8	1.3	1.4	2.4
30	1.2	.....	5.1	1.8	1.5	1.3	1.1	2.5	7.2	3.2	1.4	3.1
31	1.2	.....	6.8	.....	1.5	.....	1.0	2.2	.....	78	.....	2.3
1913.												
1	1.3	1.3	1.3	2.4	1.4	1.6	13	1.6	0.7	0.9	0.6	2.0
2	1.3	1.3	1.3	2.2	1.4	1.6	27	1.6	.7	.7	.6	1.7
3	1.2	1.3	1.3	1.6	1.4	1.6	6	1.6	1.0	.9	22	1.2
4	1.2	1.3	1.3	1.4	1.4	1.6	3.4	1.6	.9	.8	20	24
5	1.2	1.3	1.3	1.4	1.4	1.6	26	1.6	.7	.7	1.0	4.0
6	1.1	1.4	1.3	1.3	1.4	2.4	6.0	3.2	.6	8.6	1.0	2.9
7	1.1	1.4	1.3	1.3	1.4	2.7	3.9	2.0	.6	1.0	2.9	2.3
8	1.2	22	1.3	1.3	1.4	2.3	2.6	1.7	.7	15	4.8	2.1
9	1.2	1.4	1.3	2.7	1.4	4.1	1.9	1.6	.6	1.2	57	2.0
10	1.3	1.4	1.3	1.4	1.3	7.9	2.0	2.0	.7	.5	36	1.7
11	1.3	1.3	1.3	78	1.3	1.7	1.9	1.7	1.4	.6	12	1.4
12	1.3	1.3	1.2	44	1.7	5.5	4.8	66	.9	.8	6.3	1.5
13	12	1.3	1.2	85	3.0	6.0	6.3	2.0	2.0	32	4.0	1.6
14	12	1.3	1.2	12	32	1.8	2.8	4.0	.9	4.8	1.4	1.6
15	8.6	1.3	1.5	88	12	1.7	2.3	2.2	.8	1.2	1.4	1.6
16	1.6	1.4	1.4	15	3.9	1.7	1.9	9.8	1.5	.6	12	1.6
17	1.3	1.3	2.2	18	3.5	1.5	1.9	2.3	7.1	.6	17	1.6
18	1.1	8.0	1.4	5.6	4.6	1.5	1.9	.8	30	.7	50	12
19	1.1	7.0	1.4	2.4	5.5	1.4	2.0	1.0	1.1	.6	18	2.4
20	1.0	1.4	1.3	2.4	2.9	1.4	2.3	.9	.7	.7	2.2	1.6
21	1.2	1.5	4.3	2.4	1.9	1.4	1.9	.9	.9	.7	1.6	1.5
22	1.1	1.4	8.0	2.0	1.9	1.4	2.0	.9	.9	.7	1.4	1.5
23	1.1	1.4	1.4	3.6	1.9	1.4	4.4	.9	1.0	.7	1.3	1.5
24	1.2	1.3	1.3	1.7	3.4	1.8	2.2	1.5	.8	.9	9.8	1.5
25	1.2	3.6	2.6	6.4	2.0	2.3	2.3	1.0	.8	22	11	1.5
26	1.2	1.4	1.4	1.8	2.8	3.9	2.0	.8	.7	1.4	23	1.5
27	1.2	1.3	1.9	1.9	2.0	6.2	2.0	.8	.7	.7	4.5	1.5
28	1.2	1.3	4.7	2.2	1.7	21	1.6	1.0	.7	.7	1.7	1.4
29	1.3	.....	1.4	1.6	1.6	3.7	1.5	.8	1.0	.6	1.5	1.4
30	1.3	.....	3.2	1.6	1.6	20	1.5	.9	.8	.6	2.2	1.4
31	1.5	.....	10	.....	1.6	.....	1.5	3.1	.....	.6	.....	1.4

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Monthly discharge of Lahainaluna Stream near Lahaina, Maui, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
January	2.3	1.2	1.57	96.5	B.
February	124	1.2	13.4	771	D.
March	22	1.0	3.36	207	C.
April	46	1.5	7.23	430	C.
May	19	1.3	2.88	177	B.
June	10	1.1	2.09	124	B.
July	7.6	1.0	1.74	107	B.
August	8.0	.5	1.66	102	B.
September	16	.5	2.21	132	D.
October	78	.5	4.32	266	D.
November	132	.6	6.50	387	D.
December	55	.8	5.24	322	D.
The year	132	.5	4.31	3,120	
1913.					
January	12	1.1	2.16	133	B.
February	22	1.3	2.60	145	C.
March	10	1.2	2.17	133	C.
April	88	1.3	13.1	778	D.
May	32	1.3	3.44	212	B.
June	21	1.4	3.82	227	B.
July	27	1.5	4.61	283	C.
August	66	.8	3.93	242	B.
September	30	.6	2.06	123	B.
October	32	.6	3.31	204	C.
November	57	.6	10.9	649	D.
December	24	1.2	2.80	172	B.
The year	88	.6	4.56	2,070	

LAHAINALUNA DITCH NEAR LAHAINA, MAUI.

Location.—One and one-half miles east of Lahaina, 200 feet above intake for Lahainaluna School power house.

Records available.—May 6 to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—Ditch diverts nearly all low-water flow from Lahainaluna Stream.

Accuracy.—Records good.

Discharge measurements of Lahainaluna ditch near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 7	0.80	2.85	Sept. 30	0.72	1.92
May 12	.86	3.31	Oct. 3	.76	1.98
Aug. 19	.77	2.04			

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Daily discharge, in second-feet, of Lahainaluna ditch near Lahaina, Maui, for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.7	5.2	2.6	2.9	2.1	1.9	2.6
2	.....	2.7	5.4	2.7	2.6	1.5	2.0	2.6
3	.....	3.0	4.3	2.4	2.9	1.6	6.3	2.9
4	.....	2.7	4.6	2.4	1.9	2.1	5.2	8.1
5	.....	2.9	5.5	2.4	2.1	1.6	2.6	6.8
6	2.1	3.2	4.9	4.0	2.1	4.9	2.5	5.2
7	2.6	4.3	4.0	4.3	2.1	3.7	1.9	3.4
8	2.9	4.6	2.9	4.0	2.0	6.1	6.1	2.4
9	2.6	5.4	2.6	3.2	2.0	3.6	7.1	2.4
10	2.9	5.5	2.4	4.0	2.4	3.2	4.0	2.4
11	2.9	4.3	2.4	2.9	3.2	3.4	4.0	2.9
12	6.1	4.3	4.0	7.4	3.2	2.9	2.6	2.5
13	4.6	5.4	4.6	4.9	3.3	4.8	1.4	2.5
14	5.8	4.0	4.3	5.2	2.9	4.0	2.4	2.6
15	3.2	4.0	3.2	5.0	2.4	2.1	2.1	2.9
16	2.1	3.6	2.9	5.8	3.4	2.6	7.4	2.6
17	1.9	2.9	2.7	2.9	5.5	2.4	8.3	2.7
18	2.6	2.9	2.6	2.9	6.8	2.1	10	6.1
19	2.4	2.9	2.7	2.4	4.6	2.0	9.7	4.3
20	2.0	2.9	3.4	2.4	3.7	2.1	6.0	2.6
21	2.5	2.9	2.9	2.2	2.9	1.5	6.1	2.6
22	2.4	2.7	3.6	2.1	1.9	1.4	5.2	2.7
23	2.4	3.0	3.7	2.0	1.9	1.4	4.6	2.6
24	2.9	3.4	3.4	3.0	2.1	2.0	7.1	2.9
25	3.2	4.0	2.7	2.1	1.8	4.0	8.0	2.6
26	3.7	4.6	2.2	2.4	1.9	3.4	8.5	2.5
27	3.4	4.3	2.1	2.6	2.0	2.2	7.1	2.6
28	3.2	5.7	2.5	2.6	1.9	2.1	3.4	2.6
29	3.2	4.0	2.7	2.9	2.1	1.6	2.9	2.6
30	2.9	4.9	2.6	2.1	1.6	1.6	3.2	2.6
31	2.9	.....	2.6	4.8	.....	2.1	.....	2.6

Monthly discharge of Lahainaluna ditch near Lahaina, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
May	6.1	1.9	3.05	157	A.
June	5.7	2.7	3.79	226	A.
July	5.5	2.1	3.41	210	A.
August	7.4	2.0	3.31	204	A.
September	6.8	1.6	2.74	163	A.
October	4.9	1.4	2.65	163	A.
November	10	1.4	4.99	297	A.
December	8.1	2.4	3.21	197	A.
The period	.....	.....	.....	1,620	

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KAUAULA DITCH NEAR LAHAINA, MAUI.

Location.—About 100 feet below intake which is uppermost on the stream, about 3 miles east of Lahaina.
Records available.—October 16, 1911, to December 31, 1913.
Gage.—Vertical staff.
Discharge measurements.—Made in flume at gage.
Control.—Probably permanent.
Diversion.—Ditch diverts all low flow of Kauaula Stream.
Accuracy.—Records good.
Cooperation.—Station is maintained in cooperation with Pioneer Mill Co.

Discharge measurements of Kauaula ditch near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 15	1.26	14.7	Aug. 19	0.84	7.99
29	.92	10.5			

Daily discharge, in second-feet, of Kauaula ditch near Lahaina, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.5	6.3	6.8	7.5	8.2	6.8	15.0	6.8	7.8	5.9	5.4	10.8
2	7.5	6.0	6.6	6.8	9.2	6.4	12.8	6.8	7.7	5.7	5.4	10.5
3	8.2	6.0	6.0	6.0	9.2	6.4	12.1	6.8	7.7	5.7	15.0	9.9
4	7.5	5.6	6.0	6.0	7.8	6.4	11.4	6.8	7.5	5.7	12.8	16.4
5	6.8	5.6	6.0	4.6	7.5	6.0	15.5	6.8	7.2	5.7	8.0	15.5
6	6.8	5.6	6.0	4.6	7.5	6.3	9.2	6.9	6.9	13.7	8.0	14.6
7	6.4	6.0	6.0	5.0	7.5	6.0	11.0	6.8	6.6	8.0	6.3	13.2
8	6.4	11.9	5.6	5.0	6.8	6.0	9.2	6.8	6.6	12.8	16.0	12.1
9	6.4	9.2	5.4	6.0	6.4	9.2	8.5	6.8	6.6	7.8	16.4	11.4
10	6.4	7.5	5.3	5.3	6.4	11.0	8.2	6.8	6.6	7.2	14.6	10.1
11	6.0	7.5	5.2	18.2	6.4	7.5	7.8	6.8	6.6	6.9	14.6	8.9
12	6.0	6.8	5.0	18.2	8.0	8.4	7.8	15.5	6.6	6.4	13.7	8.4
13	11.9	6.4	4.9	18.2	15.5	10.1	9.9	12.8	6.4	11.0	12.8	8.0
14	12.8	6.4	4.9	11.0	12.8	8.4	7.8	8.9	6.4	14.2	12.4	8.4
15	14.6	6.0	6.0	18.2	12.8	7.5	7.5	9.6	6.3	7.8	12.3	7.8
16	11.9	6.0	7.8	18.2	12.8	9.2	7.4	13.2	6.6	8.0	13.2	7.8
17	9.9	6.3	6.0	18.2	13.4	7.4	7.0	11.0	8.2	6.8	15.0	7.8
18	8.9	7.0	6.0	18.2	12.8	6.8	7.0	9.0	12.4	6.6	15.0	13.7
19	8.7	15.5	5.3	14.6	12.6	6.4	6.9	8.7	8.9	6.4	.....	11.4
20	8.7	8.0	6.8	12.3	11.0	6.3	6.9	8.4	7.5	5.9	4.6	8.0
21	8.7	8.4	6.8	11.0	12.3	6.2	7.0	8.4	7.2	5.7	11.9	7.8
22	7.8	7.0	8.4	11.0	11.0	6.0	7.0	8.2	7.0	5.6	11.5	7.5
23	7.5	6.8	6.4	14.6	10.6	6.0	7.0	8.2	7.5	5.6	11.0	7.2
24	7.2	6.8	6.3	11.0	10.1	5.9	7.2	7.8	7.4	5.6	13.2	7.2
25	6.8	12.8	6.0	13.7	9.2	5.7	7.2	7.4	7.0	9.9	15.5	7.0
26	6.4	8.9	6.0	13.7	8.4	5.7	7.0	7.4	6.9	5.9	15.5	7.0
27	6.3	6.3	6.0	11.9	8.4	5.6	6.9	7.4	6.9	5.9	13.7	6.9
28	6.3	6.0	6.4	9.2	7.5	6.9	6.9	7.2	6.8	5.9	13.3	6.8
29	6.0	.....	6.0	9.2	7.5	18.2	6.9	7.2	6.6	5.7	12.8	6.6
30	6.0	.....	5.6	8.7	7.2	13.7	6.9	7.2	6.4	5.7	11.9	6.4
31	6.0	.....	12.8	.....	6.8	.....	6.8	8.7	.....	5.7	.....	6.4

NOTE.—No discharge Nov. 19.

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Monthly discharge of Kauaula ditch near Lahaina, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	14.6	6.0	7.88	485	A.
February	15.5	5.6	7.45	414	A.
March	12.8	4.9	6.27	386	A.
April	18.2	4.6	11.2	666	A.
May	15.5	6.4	9.47	582	A.
June	18.2	5.6	7.61	453	A.
July	15.5	6.8	8.57	527	A.
August	15.5	6.8	8.29	510	A.
September	12.4	6.3	7.23	430	A.
October	14.2	5.6	7.27	447	A.
November[a]	16.4	4.6	11.7	696	A.
December	16.4	6.4	9.40	578	A.
The year	18.2	4.6	8.53	6,170	

[a] Ditch was dry Nov. 19. Mean is for 29 days.

LAUNIUPOKO STREAM NEAR LAHAINA, MAUI.

Location.—About 175 feet above Pioneer Mill Co.'s ditch intake, 1 mile above storage reservoir, and about 5½ miles southeast of Lahaina.

Records available.—July 25, 1911, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably shifting.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records poor.

Cooperation.—Station maintained in cooperation with Pioneer Mill Co.

Discharge measurements of Launiupoko Stream near Lahaina, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 17	0.84	6.05
Aug. 20	.45	.94

Monthly discharge of Launiupoko Stream near Lahaina, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	5.5	0.8	1.11	68.2	D.
February	3.9	.8	1.16	64.4	D.
March	1.4	.8	.83	51.0	D.
April	12	.8	2.86	170	D.
May	25	.8	2.99	184	D.
June	2.8	.8	1.02	60.7	D.
July	2.0	.8	.92	56.6	D.
August	5.5	.8	1.14	70.1	D.
September	1.5	.8	.82	48.8	D.
October	3.6	.8	1.06	65.2	D.
November	6.9	.8	2.12	126	D.
December	6.7	.8	1.08	66.4	D.
The year	25	.8	1.43	1,030	

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OLOWALU STREAM NEAR OLOWALU, MAUI.

Location.—About 600 feet above Olowalu Sugar Co.'s power house, about 1 mile north of Olowalu.

Record available.—April 26 to December 31, 1913.

Gage.—Vertical staff.

Control.—Fairly permanent.

Discharge measurements.—Made from footbridge or by wading.

Diversions.—Water for power house diverted about 1½ miles above gage; measured in tailrace called Olowalu ditch No. 1.

Accuracy.—Records fair.

Cooperation.—Station maintained in cooperation with Olowalu Sugar Co.

Discharge measurements of Olowalu Stream near Olowalu, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 26	0.83	3.44	Aug. 20	0.50	0.10
May 15	1.77	55.8			

Daily discharge, in second-feet, of Olowalu Stream near Olowalu, Maui, for 1913.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		0.4	0.4	21		0.2			1.2
2		1.6	.3	11		.3			.4
3		.4	2.6	25				32	.3
4		.4	.4	11				18	84
5		.2	.2	1.9				6.3	34
6				7.6				.1	29
7		.2	.3	2.9					19
8			8.0	2.4				42	12
9			.3	1.9				102	10
10			4.0	1.9				60	7.6
11			.2	.3				35	6.6
12		46			28			29	5.6
13		37	7.0	18	.5		1.6	28	5.0
14		134	7.0		2.6		.1	15	5.6
15		86	2.6		7.3			2.7	.9
16		36	.4		11			.3	.2
17		24	.8		18			5.3	.1
18		21	.2		4.5	4.0		16	12
19		16	2.4		5.6			40	.3
20		13	.2		77			38	.2
21		11			13			7.6	.1
22		9.0			39		7.0	2.4	
23		5.3			1.1		1.1	.4	
24		7.0			.2		.2	1.9	
25		69			.2			28	
26	2.9	1.2			.2			50	
27	5.1		5.6		.2			18	
28	1.6	107	5.9		.2			7.0	
29	1.1	5.3	126		.2			2.3	
30	.6	1.8	11		.2			4.5	
31		.2			1.0				

NOTE.—No discharge for days for which figures are not given; water diverted above station at power house.

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Monthly discharge of Olowalu Stream near Olowalu, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
April 27-30	5.1	0.6	2.26	22.4	C.
May	134	(a)	20.4	1,250	C.
June	126	(a)	6.19	368	C.
July	25	(a)	3.38	208	C.
August	77	(a)	6.77	416	C.
September	4.0	(a)	.15	8.9	C.
October	7.0	(a)	.32	19.7	C.
November	102	(a)	19.7	1,170	C.
December	84	(a)	7.55	464	C.
The period				3,930	

a Stream dry.

OLOWALU DITCH NO. 1 NEAR OLOWALU, MAUI.

Location.—One mile above Olowalu, near Olowalu plantation power house, and about 7 miles east of Lahaina.

Records available.—August 12, 1911, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made in flume.

Accuracy.—Records good.

Cooperation.—Station maintained in cooperation with Olowalu Sugar Co.

Discharge measurements of Olowalu ditch No. 1 near Olowalu, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 16	0.38	5.31
Aug. 20	.49	8.04

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Daily discharge, in second-feet, of Olowalu ditch No. 1 near Olowalu, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.5	4.5	5.5	6.0	8.0	4.5	10	5.0	4.5	3.9	3.9	11
2	4.5	4.0	5.5	5.5	8.5	4.5	10	4.5	4.5	4.0	4.0	11
3	4.5	4.0	5.0	5.0	8.0	5.5	10	4.5	4.5	4.0	4.8	11
4	4.0	4.0	4.5	4.0	8.0	4.5	8.5	4.5	4.5	4.0	5.5	15
5	4.5	4.0	4.5	4.0	7.0	4.5	8.0	4.5	4.5	4.0	4.8	13
6	4.5	6.0	4.5	4.0	6.0	4.5	7.5	4.5	4.5	4.9	4.8	11
7	4.5	8.0	4.5	4.0	6.0	4.5	5.5	4.5	4.5	4.0	4.8	11
8	4.5	5.5	4.5	4.0	5.5	4.5	5.5	4.5	4.0	5.5	8.0	9.5
9	4.5	4.0	4.5	4.0	5.5	4.5	5.5	4.5	4.0	4.3	4.8	7.5
10	4.5	4.5	4.0	4.5	5.5	4.5	5.5	5.0	4.0	4.0	3.8	6.8
11	4.0	5.0	4.0	9.5	6.0	4.0	5.5	4.5	4.0	3.9	3.8	5.5
12	4.0	4.5	4.0	4.5	5.5	4.5	7.0	6.0	4.0	3.8	3.0	5.5
13	10	4.5	4.0	4.5	10	5.5	8.0	4.5	4.0	6.5	4.0	4.9
14	7.5	4.5	6.0	9.5	8.0	4.5	8.0	8.0	4.0	8.0	4.0	5.2
15	4.5	4.5	6.0	11	4.5	5.0	7.0	8.0	4.0	5.2	6.0	5.8
16	5.0	4.5	7.5	6.0	7.0	4.5	7.0	8.0	4.0	4.3	9.5	7.5
17	4.5	4.5	7.5	4.5	10	4.5	5.5	7.5	5.0	4.0	11	8.0
18	4.0	5.5	5.5	4.0	9.5	4.0	5.5	8.0	8.0	4.0	11	11
19	4.0	8.0	5.0	6.0	9.0	4.0	6.0	8.0	6.0	4.0	11	8.0
20	3.5	7.0	4.5	11	6.0	4.0	7.5	7.5	5.0	3.9	9.5	8.0
21	3.0	5.5	5.0	11	5.5	4.0	7.0	7.0	4.5	3.8	11	8.0
22	4.5	4.5	7.5	7.5	5.5	4.0	5.5	7.0	4.5	4.0	11	6.8
23	4.5	4.0	6.0	5.0	5.5	4.5	6.0	6.0	4.5	6.8	11	6.8
24	4.5	3.5	5.0	6.0	5.5	5.5	6.0	5.5	4.0	7.5	11	6.0
25	4.5	7.0	5.0	8.0	5.5	5.5	5.5	5.5	4.0	6.0	13	5.5
26	4.0	5.0	4.5	8.5	5.5	5.5	5.5	5.0	4.0	5.5	13	5.5
27	4.0	4.0	5.0	8.5	5.0	8.0	5.5	5.0	4.0	5.2	12	5.5
28	4.0	4.5	6.0	8.5	5.5	8.5	5.5	4.5	4.0	5.2	11	5.5
29	4.0	.....	4.5	8.0	5.5	9.5	5.0	4.5	4.0	5.2	11	5.5
30	4.0	.....	5.0	8.0	5.0	9.5	4.5	4.5	4.0	4.8	11	5.4
31	4.5	.....	8.0	.....	5.0	.....	4.5	7.0	.....	5.5	.....	5.2

Monthly discharge of Olowalu ditch No. 1 near Olowalu, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	10	3.0	4.55	280	B.
February	8.0	3.5	4.96	275	B.
March	8.0	4.0	5.24	322	B.
April	11	4.0	6.48	386	B.
May	10	4.5	6.53	402	B.
June	9.5	4.0	5.17	308	B.
July	10	4.5	6.56	403	B.
August	8.0	4.5	5.73	352	B.
September	8.0	4.0	4.43	264	B.
October	8.0	3.8	4.85	298	B.
November	13	3.0	7.90	470	B.
December	15	4.9	7.80	480	B.
The year	15	3.0	5.86	4,240	

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WAIKAPU STREAM NEAR WAIKAPU, MAUI.

Location.—One and one-half miles west of Waikapu and about 5 miles southwest of Wailuku; 500 feet below intake of Palolo ditch.
Records available.—December 1, 1910, to December 31, 1913.
Gage.—Inclined staff.
Control.—Shifting.
Discharge measurements.—Made by wading.
Diversions.—Most of the normal flow diverted into the South Side Waikapu and the Palolo ditches.
Accuracy.—Records poor on account of insufficient rating.

The following discharge measurement was made by C. T. Bailey:
May 27, 1913: Gage height, 0.34 foot; discharge, 0.20 second-foot.

Monthly discharge of Waikapu Stream near Waikapu, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	0.3	0.2	0.20	12.3	D.
February	50	.2	4.70	261	D.
March	.3	.2	.21	12.9	D.
April	81	.2	10.3	613	D.
May	181	.2	8.94	550	D.
June	27	.2	1.60	95.0	D.
July	6.0	.2	.53	32.6	D.
August	25	.2	3.05	188	D.
September	.8	.2	.22	13.1	D.
October	1.0	.2	.25	15.4	D.
November	149	.2	9.30	553	D.
December	178	.2	13.6	836	D.
The year	181	.2	4.40	3,180	

SOUTH SIDE WAIKAPU DITCH NEAR WAIKAPU, MAUI.

Location.—One mile below ditch intake, 1½ miles west of Waikapu, and about 5½ miles southwest of Wailuku.
Records available.—November 21, 1910, to December 31, 1913.
Gage.—Vertical staff.
Control.—Fairly permanent.
Discharge measurements.—Made from plank over ditch about 400 feet below gage.
Accuracy.—Records good.

Discharge measurements of South Side Waikapu ditch near Waikapu, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 9	0.57	3.47	July 29	0.60	3.78
May 27	.73	6.29	Nov. 5	.66	4.86

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Daily discharge, in second-feet, of South Side Waikapu ditch near Waikapu, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.5	2.8	4.8	4.2	5.7	6.0	9.0	4.2	6.0	3.4	2.9	6.0
2	4.1	2.8	4.2	4.1	8.8	6.0	9.4	4.8	6.0	3.4	3.1	6.0
3	4.5	2.8	4.2	3.9	6.8	6.2	7.5	4.2	5.7	3.1	10.4	5.6
4	3.9	2.8	4.1	3.6	7.0	6.0	6.7	4.2	5.4	3.4	9.0	14.5
5	3.5	2.8	3.9	3.5	7.6	6.0	5.7	4.2	5.4	3.1	5.4	8.5
6	3.1	10.1	3.9	3.5	8.2	6.0	5.9	4.1	5.0	3.6	4.2	6.0
7	3.1	5.9	4.2	3.5	8.5	5.9	6.7	3.9	5.7	3.2	3.8	4.5
8	2.9	11.0	4.2	3.5	8.3	6.3	5.7	3.8	4.2	4.4	17.3	4.2
9	2.8	7.1	3.9	3.5	8.5	6.0	5.1	3.9	4.2	3.4	15.7	.6
10	2.8	5.0	3.9	3.9	8.3	6.7	4.5	7.0	3.9	3.1	10.8	7.3
11	2.8	5.1	3.9	8.3	8.2	6.3	4.2	4.5	4.4	2.8	8.3	6.7
12	2.8	4.2	3.9	11.0	12.6	8.0	7.0	10.8	3.9	2.8	7.1	6.2
13	4.1	3.5	3.9	11.3	10.6	6.8	6.2	8.7	4.6	3.9	7.1	5.8
14	4.5	3.5	3.9	10.6	11.0	6.0	5.7	6.0	3.9	2.9	6.0	5.4
15	4.5	3.5	4.4	13.7	8.0	7.6	5.4	6.3	3.8	3.1	5.2	4.5
16	3.5	3.6	4.5	12.2	6.7	6.2	5.2	10.1	4.2	2.9	6.3	4.2
17	3.1	3.5	5.1	11.9	8.7	5.7	5.2	8.3	4.4	2.9	7.3	4.6
18	2.8	10.4	4.4	10.8	9.0	5.6	5.2	6.2	7.6	2.8	11.2	5.1
19	2.8	6.5	4.1	8.7	9.0	5.1	5.2	5.1	5.1	2.8	13.2	4.2
20	2.8	9.0	3.6	7.3	7.8	4.5	5.4	5.4	4.2	2.8	8.3	3.9
21	2.8	6.5	3.5	8.5	7.1	4.2	5.1	5.7	4.4	2.7	7.0	3.8
22	2.8	5.7	5.1	8.2	7.0	4.1	4.5	4.8	3.9	2.7	5.7	2.8
23	2.8	5.6	4.2	7.8	6.5	4.1	5.1	5.1	3.9	2.7	6.3	2.8
24	2.8	4.2	3.9	7.6	6.0	4.1	5.1	5.1	3.6	2.7	8.3	2.8
25	2.8	7.6	3.9	7.3	6.0	4.2	5.7	5.4	3.5	2.8	9.4	2.8
26	2.8	7.3	3.6	6.2	8.8	3.9	4.8	5.1	3.5	2.7	12.6	2.8
27	2.8	5.7	3.5	6.3	6.8	11.2	4.5	6.2	3.5	2.7	8.3	2.7
28	2.8	5.6	5.0	5.7	6.3	9.4	3.9	6.0	3.5	2.8	6.8	2.7
29	2.8	.....	4.1	5.7	6.0	8.8	3.9	5.4	3.4	3.0	5.7	2.7
30	2.8	.....	3.5	5.9	5.9	9.4	4.5	5.4	3.4	3.1	8.3	2.5
31	3.5	.....	5.0	.....	5.7	.....	4.2	9.9	.....	2.9	.....	2.5

Monthly discharge of South Side Waikapu ditch near Waikapu, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	4.5	2.8	3.21	197	A.
February	11.0	2.8	5.50	305	A.
March	5.1	3.	4.14	255	A.
April	13.7	3.5	7.07	421	A.
May	12.6	5.7	7.79	479	A.
June	11.2	3.9	6.21	370	A.
July	9.4	3.9	5.55	341	A.
August	10.8	3.8	5.80	357	A.
September	7.6	3.4	4.47	266	A.
October	4.4	2.7	3.05	187	A.
November	17.3	2.9	8.03	478	A.
December	14.5	.6	4.67	287	A.
The year	17.3	.6	5.45	3,940	

PALOLO DITCH NEAR WAIKAPU, MAUI.

Location.—Two hundred feet below ditch intake, 1½ miles west of Waikapu, and about 5½ miles southwest of Wailuku.

Records available.—November 21, 1910, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Accuracy.—Records good.

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Discharge measurements of Palolo ditch near Waikapu, Maui, in 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 9	0.81	2.61	July 29	0.80	2.24
May 27	.84	2.83			

Daily discharge, in second-feet, of Palolo ditch near Waikapu, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.8	2.8	2.8	2.5	2.4	2.6	3.2	2.4	2.6	2.4	2.4	2.6
2	2.9	2.6	2.8	2.5	3.1	2.7	3.4	2.6	2.5	2.4	2.5	2.6
3	3.1	2.6	2.6	2.5	2.8	2.8	3.1	2.5	2.6	2.4	2.5	2.5
4	3.0	2.6	2.5	2.5	2.6	2.6	2.9	2.5	2.5	2.4	2.8	3.5
5	3.0	2.6	2.5	2.5	2.5	2.6	2.6	2.5	2.5	2.4	2.5	2.8
6	3.0	4.3	2.5	2.5	2.4	2.6	2.8	2.4	2.5	2.5	2.4	2.9
7	3.0	3.5	2.5	2.5	2.5	2.6	3.0	2.4	2.8	2.4	2.4	6.0
8	3.0	4.5	2.5	2.5	2.4	2.6	2.6	2.4	2.5	2.5	5.2	5.9
9	3.0	3.4	2.5	2.5	2.4	3.0	2.6	2.4	2.5	2.4	3.8	2.7
10	3.0	2.8	2.5	2.6	2.4	3.3	2.6	3.7	2.4	2.4	3.0	3.4
11	3.0	2.8	2.5	4.8	2.4	3.0	2.5	2.6	2.5	2.4	2.9	1.4
12	3.0	2.6	2.5	3.9	3.5	3.1	3.4	3.9	2.4	2.4	2.8	2.3
13	3.1	2.6	2.5	3.8	3.1	2.9	3.0	3.4	2.6	2.5	2.8	2.0
14	3.4	2.6	2.5	3.8	3.6	2.7	2.8	2.6	2.4	2.6	2.6	2.2
15	3.2	2.5	2.8	3.9	3.6	3.0	2.6	2.7	2.4	2.6	2.5	2.0
16	3.0	2.6	2.8	3.9	3.4	2.9	2.5	4.2	2.5	2.5	2.6	2.0
17	3.0	2.9	2.6	3.9	3.3	2.6	2.5	3.5	2.5	2.4	2.9	2.0
18	3.0	3.4	2.5	3.8	3.2	2.5	2.5	2.8	2.9	2.4	3.1	2.1
19	2.9	3.4	2.5	3.4	3.3	2.5	2.5	2.6	2.6	2.4	3.3	2.3
20	2.8	3.4	2.5	3.1	3.0	2.5	2.7	2.6	2.5	2.4	2.9	2.4
21	2.9	3.2	2.5	3.4	2.9	2.5	2.5	2.6	2.5	2.4	2.6	2.4
22	2.8	3.1	2.8	3.1	2.9	2.5	2.5	2.5	2.4	2.4	2.6	2.5
23	2.8	3.0	2.6	3.0	2.6	2.5	2.6	2.6	2.4	2.4	2.6	2.5
24	2.8	2.8	2.5	2.6	2.6	2.4	2.5	2.6	2.4	2.4	2.6	2.5
25	2.8	3.4	2.5	2.6	2.6	2.5	2.6	2.6	2.4	2.5	2.8	2.5
26	2.6	3.2	2.5	2.5	3.1	2.4	2.6	2.5	2.4	2.4	3.5	2.5
27	2.6	3.0	2.5	2.5	2.8	3.8	2.5	2.8	2.4	2.4	2.8	2.5
28	2.6	2.8	2.8	2.4	2.6	3.6	2.5	2.6	2.4	2.9	2.5	2.5
29	2.6	.....	2.5	2.4	2.5	3.3	2.5	2.5	2.4	3.3	2.5	2.6
30	2.6	.....	2.5	2.4	2.5	3.4	2.6	2.5	2.4	2.5	2.8	2.6
31	2.8	.....	2.5	.....	2.5	.....	2.5	4.0	.....	2.4	.....	2.6

Monthly discharge of Palolo ditch near Wailuku, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	3.4	2.6	2.91	179	A.
February	4.5	2.5	3.04	169	A.
March	2.8	2.5	2.57	158	A.
April	4.8	2.4	3.01	179	A.
May	3.6	2.4	2.81	173	A.
June	3.8	2.4	2.79	166	A.
July	3.4	2.5	2.70	166	A.
August	4.2	2.4	2.78	171	A.
September	2.9	2.4	2.49	148	A.
October	3.3	2.4	2.48	152	A.
November	5.2	2.4	2.87	171	A.
December	6.0	1.4	2.69	165	A.
The year	6.0	1.4	2.76	2,000	

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HAIPUAENA STREAM NEAR HUELO, MAUI (OLD STATION).

Location.—About 7 miles by trail east of Huelo post office, about 400 feet below point where Spreckels ditch joins the stream.
Records available.—December 18, 1910, to September 30, 1913.
Gage.—Vertical staff.
Control.—Shifting.
Discharge measurements.—Made by wading.
Diversions.—Combined flow of stream and Spreckels ditch was measured.
Accuracy.—Poor.
Cooperation.—Station is maintained in cooperation with East Maui Ditch Co.

Monthly discharge of Haipuaena Stream near Huelo, Maui, for 1913.

[Old station.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	80	9.0	27.7	1,700	D.
February	100	8.5	20.6	1,140	D.
March	65	4.5	19.4	1,190	D.
April	136	14	46.8	2,780	D.
May	79	14	23.8	1,460	D.
June	72	10	24.6	1,460	D.
July	56	7.0	24.7	1,520	D.
August	96	5.5	25.2	1,550	D.
September	90	8.0	17.8	1,060	D.
The period				13,900	

HAIPUAENA STREAM NEAR HUELO, MAUI (NEW STATION).

Location.—Seven miles east of Huelo post office, 200 feet above Spreckels ditch inflow.
Records available.—October 19 to December 31, 1913.
Gage.—Friez water-stage recorder.
Control.—Probably permanent.
Discharge measurements.—Made from footbridge or by wading.
Diversions.—None above station.
Accuracy.—Records very good.

Discharge measurements of Haipueno Stream near Huelo, Maui, in 1913.

[New station.]

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Oct. 27	E. O. Christiansen	0.42	2.77	Nov. 12	C. T. Bailey	2.10	81.0
Nov. 4	do	1.38	33.6	Nov. 13	do	1.01	14.9
Nov. 8	do	2.46	141	Nov. 18	do	2.72	161

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Daily discharge, in second-feet, of Haipuaena Stream near Huelo, Maui, for 1913.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	.....	4	7	11	.....	28	8	21	4	39	7
2	.....	15	7	12	.....	58	8	22	4	27	6
3	.....	71	11	13	.....	19	14	23	3	15	6
4	.....	32	174	14	.....	11	37	24	3	83	5
5	.....	10	85	15	.....	14	23	25	3	31	5
6	.....	7	61	16	.....	28	12	26	3	42	5
7	.....	14	17	17	.....	41	18	27	3	21	4
8	.....	100	20	18	.....	138	33	28	3	12	4
9	.....	150	13	19	4	136	11	29	3	10	4
10	.....	62	9	20	4	52	8	30	3	8	4
								31	3	.....	4

NOTE.—Discharge interpolated Nov. 16 and 22.

Monthly discharge of Haipuaena Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
October 19-31	4	3	3.3	85	A.
November	150	4	42.6	2,530	A.
December	174	4	20.3	1,250	A.

PUOHAKAMOA STREAM NEAR HUELO, MAUI (OLD STATION).

Location.—About 6 miles by trail east of Huelo post office, immediately below point where Spreckels ditch falls into stream.

Records available.—December 18, 1910, to June 18, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—Measurement made of combined flow of stream and Spreckels ditch.

Accuracy.—Records poor.

Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

Monthly discharge of Puohakamoa Stream near Huelo, Maui, for 1913.

[Old station.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	106	16	38.7	2,380	D
February	169	15	35.0	1,940	D.
March	489	6	39.1	2,400	D
April	209	20	77.7	4,620	D
May	177	18	36.9	2,270	D.
June 1-18	100	18	34.3	1,220	D.
The period	.....	.....	.....	14,800	

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PUOHAKAMOA STREAM NEAR HUELO, MAUI (NEW STATION).

Location.—Seven miles east of Huelo post office, 150 feet above Spreckels ditch trail.
Records available.—June 13 to December 31, 1913.
Gage.—Barrett & Lawrence water-stage recorder.
Control.—Fairly permanent.
Discharge measurements.—Made from trail bridge or by wading.
Diversions.—Kula pipe line diverts water at an elevation of 4,300 feet.
Accuracy.—Low-water records good; records for high stages only approximate.

Discharge measurements of Puohakamoa Stream near Huelo, Maui, in 1913.

[New station.]

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 19	C. T. Bailey	1.26	[a] 7.70	Nov. 12	C. T. Bailey	3.18	130
Oct. 27	E. O. Christiansen	.94	[a] 6.49	Nov. 13	do	2.40	37.6

[a] Discharge is the difference between measured discharge of Spreckels ditch above and below Puohakamoa Stream.

Daily discharge, in second-feet, of Puohakamoa Stream near Huelo, Maui, for 1913.

[New station.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	11	6.2	.....	6.5	6.6	14
2	.....	43	6.2	.....	6.0	15	12
3	.....	21	6.1	.....	5.8	128	16
4	.....	20	5.8	.....	6.2	68	366
5	.....	36	5.8	.....	6.2	16	178
6	.....	52	7.1	.....	15	11	147
7	.....	21	40	.....	27	13	55
8	.....	16	8.4	.....	37	226	61
9	.....	12	7.4	.....	12	305	34
10	.....	10	7.4	.....	8.5	153	21
11	.....	10	74	.....	8.2	79	17
12	.....	11	76	.....	7.6	129	16
13	53	11	17	.....	17	47	15
14	24	11	15	.....	11	22	79
15	16	10	15	.....	9.1	20	62
16	10	9.0	12	.....	8.0	66	26
17	8.7	8.7	9.7	13	7.4	100	37
18	8.1	8.0	8.6	24	7.2	267	91
19	7.8	7.6	8.1	22	7.0	233	23
20	7.4	7.8	7.8	10	6.8	92	17
21	7.1	8.1	7.6	8.7	6.9	68	14
22	7.0	7.4	7.2	7.8	6.6	28	13
23	7.0	7.2	7.0	7.4	6.4	31	12
24	7.0	7.2	7.0	7.0	6.3	173	11
25	7.0	7.2	6.8	6.7	6.2	91	10
26	7.0	7.2	6.8	6.5	6.2	114	9.7
27	7.0	7.2	6.9	6.5	6.2	57	9.3
28	7.0	7.0	7.3	6.5	6.2	26	8.9
29	7 0	6.8	7.0	6.4	6.1	21	8.7
30	9.5	6.6	16	6.1	6.0	16	8.1
31	.....	6.5	8.8	.....	6.0	.....	7.8

NOTE.—No record Sept. 1-16; recording instrument out of order.

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Monthly discharge of Puohakamoa Stream near Huelo, Maui, for 1913.

[New station.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
June 13-30	53	7.0	11.5	410	A.
July	52	6.5	13.4	824	A.
August	76	5.8	13.9	855	A.
September 17-30	24	6.1	9.90	275	A.
October	37	5.8	9.31	572	A.
November	305	6.6	87.4	5,200	C.
December	366	7.8	45.1	2,770	B.
The period				10,900	

ALO STREAM NEAR HUELO, MAUI.

Location.—About 5 miles by trail east of Huelo post office, immediately below bridge where old Spreckels ditch trail crosses stream.

Records available.—December 18, 1910, to December 31, 1913.

Gage.—Vertical staff.

Control.—Affected by backwater from inflow of Spreckels ditch.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records poor.

Discharge measurements of Alo Stream near Huelo, Maui, for 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 24	1.48	1.45	Nov. 20	2.11	18.2
Nov. 18	2.58	31.9			

Monthly discharge of Alo Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	24	1.1	4.80	295	D.
February	61	.8	4.72	262	D.
March	7.8	.5	2.65	164	D.
April	51	1.7	11.7	696	D.
May	28	1.2	3.56	219	D.
June	9.4	1.2	3.33	198	D.
July	21	.7	3.75	231	D.
August	43	.5	4.30	264	D.
September	11	.7	2.04	121	D.
October	15	.4	2.73	168	D.
November	97	.7	22.8	1,360	D.
December	110	1.2	10.7	658	D.
The year	110	.4	6.40	4,640	

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WAIKAMOI STREAM NEAR HUELO, MAUI.

Location.—Five hundred feet above Spreckels ditch intake and 5 miles east of Huelo post office.

Records available.—December 18, 1910, to December 31, 1913.

Gage.—Friez water-stage recorder installed October 14, 1913, at new datum; staff gage December 18, 1910, to October 13, 1913.

Control.—Probably permanent.

Discharge measurements.—Made from footbridge or by wading.

Diversions.—None above station.

Accuracy.—Records good.

Discharge measurements of Waikamoi Stream near Huelo, Maui, for 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
July 24	C. T. Bailey	1.40	3.23	Nov. 8	E. O. Christiansen	1.80	163
Oct. 27[a]	E. O. Christiansen,	.35	2.15	Nov. 13	C. T. Bailey	1.03	26.2
Nov. 4	do	1.49	83.9	Nov. 2	do	1.21	53.4

[a] Water-stage recorder installed at new datum Oct. 14, 1913.

Daily discharge, in second-feet, of Waikamoi Stream near Huelo, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	10	4.0	2.6	21	6.8	5.5	25	2.2	5.7	.....	2.8	11
2	8.4	3.8	2.4	14	6.0	4.7	40	1.9	4.7	.....	12	9.4
3	7.8	3.0	2.2	8.4	7.4	4.7	14	2.0	4.4	.....	163	12
4	7.0	2.8	2.0	6.8	6.8	3.0	15	1.6	3.3	.....	67	388
5	6.2	3.6	1.8	6.4	6.4	6.0	18	1.4	2.8	.....	16	170
6	5.7	23	2.0	5.7	5.0	4.7	21	2.7	2.4	.....	12	143
7	5.0	9.2	3.3	5.0	5.0	4.6	10	4.6	2.7	.....	.....	34
8	8.8	6.0	2.6	4.4	7.8	4.4	9.2	9.6	2.6	.....	.....	29
9	9.0	4.1	4.1	6.0	5.4	5.2	7.4	5.4	2.6	.....	250	18
10	11	3.6	2.8	4.7	4.7	9.6	6.4	7.6	2.4	.....	106	13
11	6.4	3.0	1.9	48	4.1	6.6	6.0	5.8	2.0	.....	36	11
12	7.8	2.7	1.0	60	5.7	15	7.0	42	3.3	.....	104	10
13	22	2.4	.9	92	7.8	15	11	16	3.0	.....	30	9.4
14	18	2.4	.8	43	6.8	14	8.8	14	3.3	.....	18	53
15	21	2.2	.8	70	13	12	6.8	31	3.0	7.6	19	36
16	14	5.7	5.0	54	12	3.0	5.7	11	3.6	6.2	143	18
17	10	3.6	8.0	71	10	6.2	4.9	9.2	7.8	5.2	108	24
18	8.4	18	5.0	33	9.4	5.4	4.3	7.6	37	4.0	188	52
19	7.6	24	5.0	20	9.6	5.0	3.8	5.8	17	4.2	163	16
20	6.4	9.2	3.6	15	8.4	4.4	3.6	6.2	10	3.8	58	14
21	4.0	8.0	13	16	6.0	3.8	5.7	5.7	7.2	4.0	35	12
22	6.0	7.2	14	13	5.0	3.6	3.6	4.6	5.4	3.2	20	10
23	11	6.0	7.4	17	5.0	3.3	3.3	3.8	4.1	2.8	22	9.4
24	4.9	4.9	5.7	17	6.0	3.1	3.6	3.8	2.3	2.7	186	8.5
25	4.7	4.4	7.6	20	4.6	5.4	3.3	3.1	1.4	2.5	55	7.9
26	4.4	3.8	5.8	12	13	5.4	3.6	3.3	1.2	2.7	64	7.3
27	4.1	3.3	4.9	12	7.6	8.8	3.3	6.4	1.2	2.7	35	6.8
28	3.8	2.9	11	9.6	7.2	12	2.9	5.5	1.4	2.7	21	6.4
29	3.3	.....	5.8	9.0	7.6	8.2	2.6	3.8	1.2	2.3	17	6.0
30	3.1	.....	28	7.2	6.4	18	2.5	3.0	.9	2.0	12	5.6
31	3.3	.....	47	.....	8.4	.....	2.4	6.8	.....	2.1	.....	5.4

NOTE.—No record Oct. 1-14 and Nov. 7-8.

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Monthly discharge of Waikamoi Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	22	3.1	8.16	502	B.
February	24	2.2	6.31	350	B.
March	47	.8	6.71	413	B.
April	92	4.4	24.0	1,430	B.
May	13	4.1	7.25	446	B.
June	18	3.0	7.01	417	B.
July	40	2.4	8.54	525	B.
August	42	1.4	7.66	471	B.
September	37	.9	5.00	298	B.
October 15-31	7.6	2.0	3.57	110	B.
November 1-6, 9-30	250	2.8	70.1	3,890	A.
December	388	5.4	36.9	2,270	A.
The period				11,100	

OOPUOLA STREAM NEAR HUELO, MAUI.

Location.—About 2 miles by trail east of Huelo post office, about 400 feet above old Spreckels ditch crossing.

Records available.—December 16, 1910, to December 31, 1913.

Gage.—Vertical staff.

Control.—Fairly permanent.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records poor on account of only one reading daily.

Discharge measurements of Oopuola Stream near Huelo, Maui, for 1913.

[C. T. Bailey, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
June 19	1.01	0.64
Nov. 12	2.29	24.0

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Daily discharge, in second-feet, of Oopuola Stream near Huelo, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.4	0.8	0.8	16	1.6	0.8	17	0.6	0.7	0.7	0.7	4.8
2	5.0	.8	.8	15	1.2	.8	21	.6	.7	.7	1.9	2.0
3	4.8	.8	.8	1.2	1.3	.8	12	.6	.7	.7	3.2	12
4	3.4	.7	.8	8.1	1.2	1.3	2.2	.6	.7	.7	11	15
5	2.2	.6	.8	6.4	1.1	.8	2.0	.6	.7	1.4	3.4	32
6	.9	35	.8	3.6	1.1	.8	1.8	.7	.7	2.2	2.4	60
7	.8	2.9	.8	.9	.9	.8	2.0	3.9	.7	2.9	.8	32
8	12	10	.8	.9	.8	1.2	1.8	1.2	.7	27	67	4.4
9	8.1	5.4	.8	1.0	.8	1.7	1.6	1.0	.7	2.0	42	4.1
10	12	.8	.8	.8	.9	2.2	1.2	.9	.7	.8	18	3.6
11	12	1.1	.8	80	1.1	1.2	1.1	.8	.7	.8	25	2.7
12	41	.9	.8	18	1.2	3.1	.9	6.4	.7	1.6	27	3.9
13	70	.9	.8	18	1.0	15	1.0	6.4	.7	2.4	15	2.6
14	30	.9	.8	18	1.0	1.4	1.2	6.7	.7	15	10	9.3
15	34	.9	.8	21	11	1.2	1.1	34	.7	1.6	8.5	16
16	3.9	2.4	1.6	30	6.4	1.0	1.0	5.3	1.2	1.1	9.2	18
17	2.0	3.8	2.3	34	5.3	.9	.8	3.4	1.2	1.0	10	19
18	5.0	12	2.0	24	4.0	.8	.8	1.4	11	.8	67	21
19	8.5	21	1.1	22	2.7	.8	.8	1.2	4.4	.7	12	4.4
20	12	12	.9	23	1.4	.8	.8	.9	1.2	.7	9.0	3.4
21	10	2.0	2.4	24	1.2	.8	.9	.9	1.0	.7	18	2.6
22	1.4	1.4	16	44	1.1	.8	.7	.8	.8	.7	11	1.9
23	1.2	3.9	8.4	16	1.0	.8	.7	.8	.7	.7	14	1.8
24	1.1	6.4	.9	23	1.6	.8	.7	.8	.7	.7	16	1.8
25	.8	.8	1.2	30	9.8	.8	.7	.7	.7	.7	12	1.5
26	.8	.8	1.1	27	18	.9	.7	.7	.7	.7	12	1.2
27	.9	.8	.9	16	10	2.9	.7	2.9	.7	.7	14	1.2
28	.8	.8	2.5	4.4	.9	21	.7	.8	.7	.7	14	1.1
29	.8	.....	.9	3.9	.8	21	.7	.8	.7	.7	11	1.0
30	.8	.....	.8	2.9	.8	21	.7	.7	.7	.7	7.9	.9
31	.8	.....	.7	.....	.8	.....	.7	.8	.....	.7	.....	.9

NOTE.—Discharge estimated for days (usually Sundays) on which no gage heights were recorded.

Monthly discharge of Oopuola Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	70	0.8	9.37	576	D.
February	35	.6	4.60	259	D.
March	16	.7	1.80	111	D.
April	80	.8	17.8	1,060	D.
May	18	.8	2.97	183	D.
June	21	.8	3.61	215	D.
July	21	.7	2.58	159	D.
August	34	.6	2.84	175	D.
September	11	.7	1.23	73	D.
October	27	.7	2.34	144	D.
November	67	.7	15.8	937	D.
December	60	.9	9.24	567	D.
The year	80	.6	6.15	4,460	

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SPRECKELS DITCH AT GAGE NO. 1, NEAR HUELO, MAUI.

Location.—About 8½ miles by trail east of Huelo, about 20 feet above bridge which crosses ditch in Ulawina Gulch.
Records available.—December 18, 1910, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made by wading.
Accuracy.—Records good.
Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 19, 1913: Gage height, 0.40 foot; discharge, 5.94 second-feet.

Monthly discharge of Spreckels ditch at gage No. 1, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	40	4.1	13.4	824	B.
February	42	3.6	0.1	561	B.
March	36	1.6	29.90	609	B.
April	48	6.0	5.8	1,540	B.
May	28	5.5	10.1	621	B.
June	33	5.1	11.0	655	B.
July	44	3.4	13.5	830	B.
August	46	2.4	12.0	738	B.
September	40	3.7	8.05	479	B.
The period				6,860	

SPRECKELS DITCH AT GAGE NO. 2, NEAR HUELO, MAUI.

Location.—About 7½ miles by trail east of Huelo post office and 100 feet above junction of ditch with Kolea Stream No. 2.
Records available.—November 6, 1911, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from log across ditch near gage.
Accuracy.—Records good.
Cooperation.—Station is maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 19, 1913: Gage height, 0.90 foot; discharge, 6.84 second-feet.

Monthly discharge of Spreckels ditch at gage No. 2, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	36	4	13.1	806	B.
February	36	3	8.9	494	B.
March	38	2	9.3	572	B.
April	38	5	22.6	1,340	B.
May	36	5	10.8	664	B.
June	38	4	12.9	768	B.
July	35	3	12.5	769	B.
August	35	2	12.4	762	B.
September	35	3	7.5	446	B.
The period				6,620	

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SPRECKELS DITCH AT GAGE NO. 3, NEAR HUELO, MAUI.

Location.—About 6¾ miles by trail east of Huelo and 400 feet above junction of ditch with Haipuaena Stream.
Records available.—December 18, 1910, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from log near gage.
Accuracy.—Records good.
Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 19, 1913: Gage height, 1.20 feet; discharge, 9.33 second-feet.

Monthly discharge of Spreckels ditch at gage No. 3, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	40	7.4	18.3	1,120	B.
February	39	6.0	12.9	716	B.
March	41	3.6	13.5	830	B.
April	45	8.7	27.4	1,630	B.
May	40	7.9	15.7	965	B.
June	40	5.8	16.2	964	B.
July	38	5.8	17.0	1,050	B.
August	39	4.6	15.7	965	B.
September	38	6.0	11.5	684	B.
The period	.....	.....	.....	8,920	

SPRECKELS DITCH AT GAGE NO. 4, NEAR HUELO, MAUI.

Location.—About 6¼ miles by trail east of Huelo and about 250 feet above junction with small tributary of Puohakamoa Stream.
Records available.—December 18, 1910, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from log at gage.
Accuracy.—Records fair.
Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 19, 1913: Gage height, 0.90 foot; discharge, 12.2 second-feet.

Monthly discharge of Spreckels ditch at gage No. 4, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	38	9.5	21.2	1,300	C.
February	36	7.5	15.2	844	C.
March	40	4.0	14.6	898	C.
April	44	11.5	27.8	1,650	C.
May	38	9.5	18.3	1,130	C.
June	38	9.5	18.3	1,090	C.
July	36	5.5	19.0	1,170	C.
August	40	4.5	17.3	1,060	C.
September	38	7.0	13.7	815	C.
The period	.....	.....	.....	10,000	

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SPRECKELS DITCH AT GAGE NO. 5, NEAR HUELO, MAUI.

Location.—About 5 miles east of Huelo and about 500 feet above drop into Alo Stream.
Records available.—November 6, 1911, to September 30, 1913.
Gage.—Vertical staff.
Control.—Probably permanent.
Discharge measurements.—Made from plank at gage.
Accuracy.—Records good.
Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 4, 1913: Gage height, 1.10 feet; discharge, 21.6 second-feet.

Monthly discharge of Spreckels ditch at gage No. 5, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	55	16	33.7	2,070	B.
February	54	13	24.6	1,370	B.
March	53	9	24.3	1,490	B.
April	58	19	43.4	2,580	B.
May	51	18	30.3	1,860	B.
June	55	16	28.2	1,680	B.
July	56	13	31.5	1,940	B.
August	66	16	30.4	1,870	B.
September	55	14	21.7	1,290	B.
The period				16,200	

SPRECKELS DITCH AT GAGE NO. 6, NEAR HUELO, MAUI.

Location.—About 3½ miles east of Huelo and 100 feet below Kolea Stream intake.
Records available.—November 4, 1911, to June 30, 1913.
Gage.—Vertical staff.
Discharge measurements.—Made from log at gage.
Control.—Probably permanent.
Accuracy.—Records good.
Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 14, 1913: Gage height, 1.35 feet; discharge, 44.5 second-feet.

Monthly discharge of Spreckels ditch at gage No. 6, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	52	30	33.4	2,050	B.
February	46	24	30.6	1,700	B.
March	42	18	31.8	1,960	B.
April	99	34	45.5	2,710	B.
May	50	31	42.4	2,610	B.
June	50	27	39.7	2,360	B.
The period				13,400	

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SPRECKELS DITCH AT GAGE NO. 8, NEAR HUELO, MAUI.

Location.—About 1 mile by trail east of Huelo and 250 feet above gate to storage reservoir.

Records available.—November 4, 1911, to September 30, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made from plank.

Accuracy.—Records fair. Discharge estimated for Sundays, when no gage record was obtained.

Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

The following discharge measurement was made by C. T. Bailey:
June 4, 1913: Gage height, 2.10 feet; discharge, 45.1 second-feet.

Monthly discharge of Spreckels ditch at gage No. 8, near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	62	5.2	17.5	1,080	C.
February	54	1.9	22.9	1,270	C.
March	54	16	34.1	2,100	C.
April	68	22	51.3	3,050	C.
May	62	33	45.4	2,790	C.
June	58	32	43.9	2,610	C.
July	59	13	40.6	2,500	C.
August	67	17	38.1	2,340	C.
September	54	22	29.8	1,770	C.
The period				19,500	

NAILIILIHAELE STREAM NEAR HUELO, MAUI.

Location.—About 300 feet above New Hamakua ditch, 3 miles south of Huelo post office.

Records available.—December 9, 1910, to December 31, 1912; October 8 to December 31, 1913.

Gage.—Barrett & Lawrence water stage recorder.

Control.—Probably permanent.

Discharge measurements.—Made from footbridge.

Diversions.—None above station.

Accuracy.—Records good.

Discharge measurements of Nailiilihaele Stream near Huelo, Maui, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Oct. 2	E. O. Christiansen	0.86	6.89	Nov. 13	C. T. Bailey	1.70	67.5
9	do	1.17	26.6	18	do	2.38	174
Nov. 3	do	1.58	52.9	19	do	3.30	514

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Daily discharge, in second-feet, of Nailiilihaele Stream near Huelo, Maui, for 1913.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	.....	3.6	32	16	14	45	46
2	.....	13	37	17	12	67	63
3	.....	158	65	18	8.5	225	110
4	.....	104	674	19	8.0	275	49
5	.....	35	245	20	8.0	122	40
6	.....	28	160	21	8.0	91	34
7	.....	27	71	22	8.0	48	31
8	156	290	91	23	7.4	38	27
9	32	365	62	24	6.8	103	25
10	15	251	48	25	6.5	106	23
11	14	111	41	26	5.3	140	18
12	12	160	37	27	5.0	86	13
13	49	91	33	28	5.0	52	13
14	42	44	144	29	3.6	44	12
15	18	37	71	30	3.6	36	12
				31	3.6	.....	11

Monthly discharge of Nailiilihaele Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
October 8-31	156	3.6	18.8	895	A.
November	365	3.6	106	6,310	A.
December	674	11.0	75.4	4,640	A.

KAILUA STREAM NEAR HUELO, MAUI.

Location.—One mile south of Huelo post office and 800 feet above Spreckels ditch, at 1,250 feet elevation.

Records available.—December 8, 1910, to December 31, 1912; June 17 to December 31, 1913.

Gage.—Barrett & Lawrence water-stage recorder October 1 to December 31; vertical staff June 17 to September 30.

Control.—Probably permanent.

Discharge measurements.—Made from footbridge or by wading.

Diversions.—Old Hamakua ditch formerly diverted water above station, but that section of ditch is not used at present time.

Accuracy.—Records good October 1 to December 31; poor remainder of period on account of uncertainty of gage heights.

Discharge measurements of Kailua Stream near Huelo, Maui, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec-ft.*			*Feet.*	*Sec.-ft.*
June 16	C. T. Bailey	1.38	8.51	Nov. 3	E. O. Christiansen	2.60	73.8
Aug. 26	E. O. Christiansen	1.23	4.37	13	C. T. Bailey	2.03	37.4
Oct. 2	do	1.14	2.96	18	do	3.42	188
9	do	1.53	19.4	19	do	3.90	270

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Daily discharge, in second-feet, of Kailua Stream near Huelo, Maui, for 1913.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	45	11	6.2	.....	4.0	21
2	.....	149	3.3	5.3	.....	30	29
3	.....	28	2.9	5.3	.....	136	22
4	.....	47	2.9	4.9	.....	65	443
5	.....	32	2.9	4.0	.....	22	283
6	.....	42	4.0	3.6	.....	16	104
7	.....	20	42	6.2	.....	31	56
8	.....	11	12	3.5	61	216	45
9	.....	7.5	6.2	3.6	13	384	26
10	.....	8.8	6.2	3.6	6.2	186	17
11	.....	8.8	4.9	3.3	5.5	70	13
12	.....	9.4	212	3.3	5.3	112	12
13	.....	17	26	3.6	12	41	11
14	.....	14	19	3.6	8.8	22	61
15	.....	8.8	91	3.6	8.0	19	69
16	.....	7.5	19	4.9	7.8	46	28
17	7.5	6.2	10	10	7.2	106	28
18	6.7	5.8	7.5	111	4.0	314	81
19	6.0	5.8	7.2	24	4.0	200	28
20	5.8	5.8	6.7	9.4	4.0	79	20
21	5.1	5.3	6.7	6.7	3.3	56	18
22	5.1	4.9	6.2	5.3	2.9	30	16
23	4.4	4.7	5.8	4.7	2.9	25	14
24	4.0	4.7	6.0	4.4	2.9	174	13
25	6.0	4.4	5.3	4.4	2.9	88	12
26	6.7	4.9	5.3	3.8	2.7	100	11
27	15	4.4	8.3	3.6	2.7	42	11
28	12	4.0	6.7	3.6	3.3	33	10
29	6.7	4.0	5.1	3.6	3.5	28	12
30	38	3.6	4.4	3.5	3.8	25	11
31	.....	3.5	24	.....	4.0	.....	11

NOTE.—No record Oct. 1-7.

Monthly discharge of Kailua Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
June 17-30	38	4.0	9.21	256	B
July	149	3.5	17.0	1,040	D.
August	212	2.9	18.7	1,150	D.
September	111	3.3	7.57	528	D.
October 8-31	61	2.7	5.86	360	A.
November	384	4.0	93.0	5,530	A.
December	443	10.0	48.6	2,990	A.
The period	.....	.....	.....	11,900	

NOTE.—Water-stage recorder installed October 1.

OANUI STREAM NEAR HUELO, MAUI.

Location.—At New Hamakua ditch crossing, 1 mile south of Huelo post office.

Records available.—December 7, 1910, to December 31, 1911; June 17 to December 31, 1913.

Gage.—Vertical staff in two sections.

Control.—Upper side of New Hamakua ditch forms permanent control.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records fair.

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Monthly discharge of Oanui Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
June 17-30	10	3.5	4.46	124	C.
July	15	3.5	4.98	306	C.
August	22	3.5	5.00	307	C.
September	8	3.5	3.75	223	C.
October	11	3.5	3.95	243	C.
November	42	3.5	12.4	738	C.
December	72	3.5	9.87	607	C.
The period	.....	.....	.....	2,550	

HOOLAWANUI STREAM NEAR HUELO, MAUI.

Location.—One-fourth mile east of Lupi and about 5 miles by trail from Huelo; 300 feet above crossing of New Hamakua ditch.

Records available.—December 12, 1910, to December 31, 1913.

Gage.—Vertical staff; datum lowered 0.20 foot June 6, 1913.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records fair.

Cooperation.—Station is maintained in cooperation with East Maui Ditch Co.

Discharge measurements of Hoolawanui Stream near Huelo, Maui, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 5	C. T. Bailey	0.30	2.84	Oct. 2	E. O. Christiansen	0.24	1.79
Aug. 27	do	.34	4.68	Nov. 19	C. T. Bailey	1.02	62.8

Daily discharge, in second-feet, of Hoolawanui Stream near Huelo, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	12	4	4	15	9	2.0	13	2.3	2.6	1.9	1.9	11
2	9	4	3	8	8	3.0	32	2.3	2.6	1.9	2.1	9.2
3	8	3	3	6	8	2.0	10	2.5	2.6	4.0	15	13
4	7	3	3	5	7	6.0	11	2.3	2.5	2.3	17	112
5	6	3	3	5	6	3.0	9.2	2.3	2.3	1.9	5	82
6	6	88	3	5	6	3.0	12	2.6	2.3	2.5	5.0	62
7	5	7	3	4	5	3.0	9.2	5.0	2.6	2.6	4.0	35
8	10	5	3	4	5	2.6	8.0	2.6	2.3	19	46	36
9	10	4	4	4	5	2.8	7.0	2.3	2.3	4.0	94	24
10	10	4	3	4	4	4.0	6.5	2.5	2.3	3.0	62	16
11	7	3	3	40	4	2.6	6.0	2.3	2.3	2.6	48	15
12	7	3	3	20	4	18	6.0	33	2.3	2.5	56	14
13	52	3	2	71	4	10	6.5	7.5	2.3	7.0	24	13
14	44	3	2	50	5	8.0	6.5	5.5	2.3	3.5	17	40
15	71	3	2	88	8	6.0	6.0	30	2.1	2.6	15	22
16	13	4	8	82	6	5.0	5.0	9.2	2.3	2.6	16	17
17	12	3	6	96	7	4.0	4.5	8.6	3.5	2.6	16	19
18	10	11	6	48	5	3.0	4.0	6.5	9.2	2.5	66	39
19	10	48	4	30	5	3.0	4.0	5.0	5.0	2.3	82	17
20	9	8	4	27	4	3.0	3.5	5.0	2.6	2.3	38	13
21	8	7	5	30	3	3.0	3.0	5.0	2.6	2.3	29	12
22	7	6	10	17	3	3.0	3.0	4.0	2.3	2.3	23	10
23	6	5	5	16	3	3.0	3.0	3.5	2.3	2.1	17	9.2
24	5	5	4	16	3	2.8	2.8	3.0	2.3	2.1	44	8.0
25	5	4	5	29	3	3.0	2.6	3.0	2.1	2.1	33	8.0
26	4	4	3	15	6	4.0	2.6	3.0	2.1	2.1	36	7.0
27	4	4	3	22	4	9.2	2.6	3.5	2.1	2.1	28	6.5
28	4	4	5	14	3	6.0	2.6	3.0	2.1	2.1	20	6.0
29	4	.....	4	14	3	4.0	2.5	2.8	2.1	2.1	17	6.0
30	5	.....	4	11	3	7.0	2.5	2.6	2.1	1.9	13	5.0
31	4	.....	16	.....	3	.....	2.5	3.0	.....	1.9	.....	5.0

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Monthly discharge of Hoolawanui Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	71	4.0	12.1	744	C.
February	88	3.0	9.04	502	C.
March	16	2.0	4.39	270	B.
April	96	4.0	26.5	1,580	B.
May	9.0	3.0	4.90	301	B.
June	18	2.0	4.63	276	B.
July	32	2.5	6.44	396	B.
August	33	2.3	5.67	349	C.
September	9.2	2.1	2.68	159	B.
October	19	1.9	3.12	192	B.
November	94	1.9	29.7	1,770	B.
December	112	5.0	22.3	1,370	B.
The year	112	1.9	10.9	7,910	

HOOLAWALIILII STREAM NEAR HUELO, MAUI.

Location.—About 400 feet above New Hamakua ditch crossing, 1½ miles east of Lupi, and about 4 miles above Huelo post office.

Records available.—April 5, 1911, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records good.

Discharge measurements of Hoolawaliilii Stream near Huelo, Maui, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 6	C. T. Bailey	0.14	3.12	Oct. 2	E. O. Christiansen	0.11	2.30
Aug. 27	E. O. Christiansen	.16	3.66	Nov. 19	C. T. Bailey	.51	31.2

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Daily discharge, in second-feet, of Hoolawaliilii Stream near Huelo, Maui, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.0	2.2	1.8	8.2	4.1	1.4	8.2	2.6	3.0	2.2	2.2	8.2
2	5.7	2.2	1.6	3.4	3.8	1.3	16	2.6	3.0	2.2	2.2	7.6
3	4.9	2.2	1.6	2.6	3.8	1.3	8.2	2.6	3.4	4.5	4.9	8.2
4	4.1	1.8	1.6	2.6	3.4	2.2	8.2	2.6	3.0	2.6	5.7	41
5	3.4	2.6	1.6	2.6	3.4	1.4	8.2	2.2	2.6	2.6	4.1	39
6	3.4	36	1.8	2.2	3.4	1.4	9.5	2.6	2.6	3.0	3.4	36
7	3.0	24	1.6	2.2	3.0	1.4	7.0	4.5	3.0	3.4	3.0	26
8	5.7	3.4	2.2	1.8	2.6	1.4	5.7	2.6	3.0	9.5	21	24
9	5.7	3.4	1.6	2.6	2.6	1.4	5.7	2.6	3.4	4.1	30	16
10	5.7	2.6	1.4	1.8	2.2	1.8	4.9	3.0	2.6	3.4	23	11
11	4.9	2.6	1.4	32	1.8	1.4	4.9	2.6	2.6	2.6	21	8.8
12	4.1	2.2	1.4	10	1.8	4.5	4.1	23	2.6	2.6	37	8.8
13	26	2.2	1.4	34	1.8	5.7	4.9	5.7	3.0	7.0	19	8.2
14	28	2.2	1.4	22	2.2	5.3	4.5	4.9	2.6	3.8	14	16
15	28	2.2	1.4	37	3.0	4.9	4.1	11	2.6	3.4	11	11
16	22	2.2	4.5	34	2.6	3.4	4.1	7.0	2.6	3.4	11	8.2
17	8.8	2.2	3.4	43	2.6	3.4	3.8	4.9	3.4	3.4	9.5	8.8
18	6.3	5.7	3.8	26	2.6	1.8	3.4	4.9	5.7	3.0	23	16
19	5.3	23	2.2	14	1.8	1.6	3.4	4.5	3.8	3.0	32	8.2
20	4.9	3.4	2.6	12	1.8	1.6	3.4	4.1	3.4	3.0	21	8.2
21	4.1	3.0	2.6	13	1.6	1.6	3.4	4.5	3.0	3.0	16	7.6
22	4.1	2.6	4.9	11	1.4	1.6	3.4	4.1	3.0	2.6	13	7.0
23	3.4	2.2	2.6	8.2	1.4	1.6	3.4	4.1	3.0	2.6	11	5.7
24	3.4	2.2	2.2	7.6	1.6	1.6	3.4	3.4	2.6	2.6	16	5.3
25	3.4	1.8	2.6	16	1.4	1.8	3.4	3.4	2.6	2.6	15	4.9
26	3.4	1.8	1.8	10	2.6	1.8	3.0	3.4	2.6	2.6	21	4.5
27	3.4	1.8	1.8	8.2	1.8	5.3	3.0	3.8	2.6	2.6	17	4.5
28	2.6	1.8	3.0	5.7	1.C	4.9	2.6	3.4	2.6	2.2	13	4.1
29	2.6	.....	2.6	5.3	1.4	3.4	2.6	3.4	2.6	2.2	11	4.1
30	2.2	.....	2.6	4.1	1.4	7.6	2.6	3.4	2.6	2.2	9.5	3.8
31	2.2	.....	9.5	.....	1.4	.....	2.6	4.1	.....	2.2	.....	3.8

Monthly discharge of Hoolawaliilii Stream near Huelo, Maui, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	28	2.2	7.15	440	B.
February	36	1.8	5.20	289	B.
March	9.5	1.4	2.47	152	B.
April	43	1.8	12.8	762	C.
May	4.1	1.4	2.32	143	B.
June	7.6	1.3	2.66	158	B.
July	16	2.6	5.02	309	B.
August	23	2.2	4.56	280	B.
September	5.7	2.6	2.97	177	B.
October	9.5	2.2	3.23	199	B.
November	37	2.2	14.7	875	B.
December	41	3.8	12.1	744	B.
The year	43	1.3	6.25	4,530	

HONOPOU STREAM NEAR HUELO, MAUI.

Location.—Three-fourths mile northwest of Lupi and about 3½ miles southwest of Huelo; 200 feet above New Hamakua ditch crossing.

Records available.—December 10, 1910, to December 31, 1913.

Gage.—Vertical staff.

Control.—Probably permanent.

Discharge measurements.—Made by wading.

Diversions.—None above station.

Accuracy.—Records good.

Cooperation.—Station maintained in cooperation with East Maui Ditch Co.

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Discharge measurements of Honopou Stream near Huelo, Maui, in 1913.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 5...	C. T. Bailey.....	0.10	1.55	Nov. 19.	C. T. Bailey.....	0.79	19.5
Aug. 27..	E. O. Christiansen.	.20	3.01				

Daily discharge, in second-feet, of Honopou Stream near Huelo, Maui, for 1912–13.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912.												
1.....	3.3	0.9	7.0	5.1	4.2	1.9	1.5	1.2	1.0	1.0	5.3	4.2
2.....	3.3	.9	8.3	4.4	4.2	1.7	1.5	1.0	2.8	1.5	4.2	13
3.....	2.9	.9	8.0	6.5	4.0	1.5	2.0	1.0	1.7	.9	7.2	25
4.....	2.9	.9	6.8	32	5.1	1.5	2.8	.9	2.8	.6	4.2	12
5.....	2.6	.9	6.2	21	3.7	1.5	1.9	.9	1.5	.6	3.3	7.8
6.....	2.6	.8	6.0	13	3.7	1.5	1.7	.9	1.5	.6	3.3	7.0
7.....	2.6	.8	6.0	18	3.3	1.4	1.9	.9	2.2	.6	2.9	7.2
8.....	2.4	.9	5.1	19	3.7	1.4	1.7	.9	1.7	.6	2.6	6.5
9.....	2.2	1.9	6.2	18	3.3	1.4	4.6	.9	1.5	.6	19	4.6
10.....	2.2	1.2	5.5	13	2.9	2.2	1.9	1.4	1.2	.6	8.6	5.1
11.....	1.9	1.2	12	12	2.8	1.9	2.6	2.2	1.2	.6	7.0	4.6
12.....	1.9	1.2	9.2	11	2.6	1.9	1.9	1.2	1.0	.6	5.1	4.2
13.....	1.9	3.3	12	9.2	2.6	1.9	1.9	1.2	1.0	.6	4.6	3.7
14.....	1.9	2.0	8.6	11	2.4	1.7	1.7	1.5	.9	49	4.2	3.7
15.....	1.7	1.4	7.5	11	2.2	1.9	1.7	3.7	.9	1.2	3.7	3.5
16.....	1.7	1.2	6.0	9.2	2.0	1.9	1.7	1.9	.9	.9	8.0	3.5
17.....	1.5	1.0	6.2	8.0	2.0	1.5	1.5	1.2	.9	.6	9.5	4.2
18.....	1.5	.9	11	7.5	2.0	1.5	1.5	1.0	.9	.6	12	4.2
19.....	1.4	2.9	6.5	7.0	2.0	1.5	1.5	.9	.8	.6	10	7.5
20.....	1.2	3.7	6.5	8.3	2.2	1.5	1.5	.9	.9	.6	7.8	5.1
21.....	1.2	6.0	5.5	6.5	2.0	1.5	1.5	.9	.8	2.9	6.2	14
22.....	1.2	7.5	5.1	5.5	1.9	1.5	1.4	1.9	.8	3.5	6.0	16
23.....	1.2	4.8	4.6	6.5	1.7	1.4	1.4	.9	.8	3.3	5.5	16
24.....	2.0	4.2	4.2	5.8	1.9	2.9	1.9	.9	.8	2.6	5.1	10
25.....	1.5	4.0	3.7	5.5	1.5	1.9	1.9	.9	.6	2.2	5.5	8.9
26.....	1.5	4.2	3.7	6.5	2.6	1.7	1.5	.8	.6	2.4	5.1	8.0
27.....	1.4	9.5	3.5	5.8	3.5	1.7	1.4	.8	.6	10	5.1	7.0
28.....	1.2	10	3.3	5.1	2.9	1.7	1.7	.8	.6	12	4.2	7.5
29.....	1.2	6.5	3.3	5.1	2.9	1.5	1.5	.9	.9	4.2	3.5	7.0
30.....	1.0	.....	3.7	4.6	2.0	1.5	1.2	.9	1.5	5.1	3.3	6.0
31.....	1.0	.....	4.4	.....	2.2	.....	1.2	.9	.....	8.3	.....	5.1
1913.												
1.....	5.5	2.2	2.0	5.5	4.6	1.4	3.7	1.2	1.5	0.9	0.9	7.0
2.....	4.6	2.2	1.9	3.3	4.2	1.2	8.6	1.2	1.5	.9	.9	6.5
3.....	4.2	2.0	1.9	2.6	4.0	1.2	4.6	1.2	1.5	.9	2.9	7.0
4.....	3.5	1.9	1.7	2.6	3.7	2.2	4.6	1.2	1.4	.9	3.5	36
5.....	3.3	1.9	1.7	2.4	3.3	1.5	4.2	1.0	1.2	.9	2.2	29
6.....	3.1	33	1.5	2.2	3.3	1.4	4.8	1.2	1.2	1.2	2.2	22
7.....	2.9	3.3	1.7	2.2	3.1	1.5	4.0	3.7	1.2	1.4	1.9	16
8.....	5.1	2.6	1.5	2.0	2.9	1.4	3.7	1.5	1.2	5.3	17	17
9.....	5.1	2.2	2.2	2.4	2.6	1.5	3.5	1.2	1.2	1.9	22	13
10.....	5.3	2.2	1.5	2.0	2.6	1.9	3.3	1.2	1.4	1.5	20	11
11.....	4.4	2.0	1.5	15	2.4	1.2	3.1	1.0	1.2	1.2	16	9.2
12.....	3.7	1.9	1.4	8.0	2.6	4.2	2.9	10	1.2	1.2	24	8.9
13.....	22	1.9	1.2	20	2.4	3.7	2.9	3.3	1.2	3.7	11	7.5
14.....	16	1.9	1.2	16	2.6	2.9	2.9	2.9	1.0	2.2	11	16
15.....	26	1.9	3.7	26	3.7	2.6	2.8	6.8	.9	1.5	9.8	10
16.....	20	2.0	2.9	21	2.9	2.2	2.6	3.5	1.2	1.4	8.3	8.6
17.....	6.5	1.9	2.9	31	3.3	1.9	2.2	3.1	1.9	1.2	7.5	9.2
18.....	5.3	4.2	2.9	17	2.6	1.5	2.2	2.8	3.3	1.2	14	12
19.....	5.1	19	2.2	12	2.6	1.5	2.0	2.6	2.0	1.2	22	8.3
20.....	4.6	3.7	2.2	11	2.2	1.5	2.0	2.6	1.2	1.0	15	7.2
21.....	3.7	3.3	2.6	13	1.9	1.5	1.9	2.6	1.2	1.0	15	6.5
22.....	3.3	3.1	4.6	9.2	1.7	1.5	1.9	2.2	1.0	1.0	10	6.0
23.....	3.3	2.9	2.6	8.0	1.7	1.5	1.7	2.0	.9	1.0	9.2	5.5
24.....	2.9	2.8	2.0	7.8	1.9	1.5	1.7	1.9	.9	.9	12	5.1
25.....	2.9	2.6	2.6	11	1.9	1.5	1.5	1.9	.9	.9	14	5.1
26.....	2.8	2.4	1.9	7.0	2.4	1.9	1.5	1.9	.9	.9	15	4.6
27.....	2.6	2.2	1.9	8.6	1.9	4.4	1.5	2.0	.9	.9	13	4.2
28.....	2.6	2.2	2.8	6.5	1.7	2.9	1.5	1.9	.9	.9	11	3.7
29.....	2.4	.....	2.2	5.8	1.5	2.2	1.4	1.9	.9	.9	8.6	3.3
30.....	2.2	.....	2.2	5.1	1.5	4.6	1.4	1.5	.9	.9	8.0	3.1
31.....	2.2	.....	6.5	.....	1.5	.....	1.2	1.9	.....	.9	.....	3.1

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Monthly discharge of Honopou Stream near Huelo, Maui, for 1912–13.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
January	3.3	1.0	1.87	115	B.
February	10	.8	2.95	170	B.
March	12	3.3	6.31	388	B.
April	32	4.4	10.0	595	A.
May	5.1	1.5	2.77	170	B.
June	2.9	1.4	1.68	100	B.
July	4.6	1.2	1.79	110	B.
August	3.7	.8	1.17	71.9	B.
September	2.8	.6	1.18	70.2	C.
October	49	.6	3.85	237	C.
November	19	2.6	6.07	361	B.
December	25	3.5	7.81	480	B.
The year	49	0.6	3.95	2,870	
1913.					
January	26	2.2	6.04	371	B.
February	33	1.9	4.12	229	C.
March	6.5	1.2	2.31	142	B.
April	31	2.0	9.54	568	B.
May	4.6	1.5	2.62	161	B.
June	4.6	1.2	2.06	123	B.
July	8.6	1.2	2.83	174	B.
August	10	1.0	2.42	149	B.
September	3.3	.9	1.26	75	B.
October	5.3	.9	1.35	83	B.
November	24	.9	10.9	649	A.
December	36	3.1	10.1	621	A.
The year	36	0.9	4.62	3,340	

MISCELLANEOUS MEASUREMENTS.

Measurements of streams on the island of Maui at points other than regular gaging stations are listed below:

Miscellaneous discharge measurements on Maui for 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.
			Feet.	*Sec.-ft.*
Mar. 15	South Waiehu	Wailuku	0.60	0.69
Apr. 9	Waikapu (North Fork)[a]	Old shops below tunnel portal	.....	2.68
9	.....do	300 feet above junction with South Fork.	.....	2.73
16	Olowalu	Olowalu	.89	51.6
16	Olowalu ditch No. 2	.....do	1.35	16.9
June 5	Nailiihaele	Huelo	.81	2.16
7	New Hamakua ditch, Gage No. 5	.....do	4.80	42.4
7	New Hamakua ditch, Gage No. 4	.....do	4.65	37.0
7	New Hamakua ditch, Gage No. 3	.....do	2.30	31.6
7	New Hamakua ditch, Gage No. 1	.....do	2.80	34.3
7	New Hamakua ditch	Halehaku Weir, Huelo	.86	73.0
June 18	Halehaku	Huelo	.25	2.63
July 21	Lower Springs	Kalepo Gulch, near Kaupo	.....	.44
21	Upper Springs	.....do	.....	.22
21	Manawainui	Below large springs, near Kaupo.	.....	2.03
21	.....do	Above large springs, near Kaupo.	.....	1.22
July 22	Alelele	Near Kipahulu	.....	.36
22	Oheo	Wooden bridge near Kipahulu	.....	1.17
22	Puaaluu	.....do	.....	2.24
22	Halalawe	.....do	.....	1.86
22	Honolewa	.....do	.....	1.29
22	Kaili	.....do	.....	1.88
23	Makapipi	Near Keanae	.....	1.71
23	East Wailuaiki	.....do	.....	7.00
Sept. 30	Lahainaluna ditch	At Intake near Lahaina	.....	2.76
30	.....do	Above Intake near Lahaina	.....	4.48
Apr. 14	Kahoma	Near Lahaina	1.16	9.21
Aug. 19	.....do	.....do	.62	.19

[a] Tributary to Waikapu Stream.

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Miscellaneous discharge measurements on Maui for 1913—Continued.

Date.	Stream.	Locality.	Gage height.	Discharge.
			Feet.	*Sec.-ft.*
Apr. 15	Kauaula	Near Lahaina	1.35	63.4
29	do.[a]	do	.96	10.8
May 14	do	do	1.44	40.6
Aug. 19	do	do	1.04	8.84
Apr. 16	Ukumehame	Near Olowalu	1.40	72.8
21	do	do	.72	11.6
22	do.[b]	do	1.15	11.8
May 15	do	do	1.38	36.6
Aug. 20	do	do	.84	6.37
June 18	Opana	Near Huelo	1.81	.29
Nov. 18	Honomanu	Near Keanae	6.02	554
20	do	do	3.61	32

[a] New gage established May 15, 1913. [b] New datum; gage moved to better location.

ISLAND OF HAWAII.

GENERAL CONDITIONS.

The perennial streams of the Island of Hawaii are mainly included in two groups, one comprising an area about 10 miles wide, in the Kohala and Hamakua districts, and the other an area about 16 miles wide in the Hilo district between the South Branch of Wailuku River on the southeast and Maulua Gulch on the northwest.

The low water run-off from the Kohala and Hamakua districts is now practically all diverted into ditches serving the sugar lands of the north coast of the island. Only a small part of the mean run-off from the Hilo district is now being utilized, the greater part being allowed to waste into the sea.

It has been proposed to construct a high-line canal at an elevation of about 2,700 feet and carry this water to serve either the semiarid lands of Kau on the south side of the island, or the dry government lands in the vicinity of Waimea which are now being leased for cattle range.

In September, 1911, a concession was sought, and later granted, by a promotor for the construction of what was generally known as the Kau ditch project, and at the request of the territorial officials the work of investigating the run-off of the Hilo district along the 2,700-foot contour was begun. In September, October, and November, 1911, a foot trail was cut through the swamp and jungle from the South Branch of Wailuku River to the North Branch of Kawainui River, a distance of about 8 miles by trail. Staff gages were established on all appreciable channels, whether of perennial discharge or not.

Eighty-three stations were established and a camp was built about midway on the trail. Lack of funds prohibited further extension of the work and the construction of bridges or cables across the large gulches with the result that the larger streams could not be crossed when in flood. The trail was merely a passage cut through the

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jungle, over and under logs, in and out of gulches, and, for the greater part, from a few inches to several feet deep in swamp muck. Two gage readers were employed who lived in the midway camp and who went over the trail once a day on an average of about four days in the week and read the gages—one man working south and the other north and return. The condition of the trail was such that about eight hours were necessary to cover the 8-mile trip. All supplies for the camp and work were packed in on men's backs from the end of the Kaiwiki homestead road, a distance of about 3½ miles. One day of the week was allowed the observers for packing in supplies, and one day for rest. Up until May, 1913, when funds became available for the construction of cableways across the larger gulches, many daily records were lost on account of the observers being unable to cross these gulches when in flood. On account of the flashy type of the streams it was found that two readings daily, within a few hours of each other, gave a very poor index of the daily mean gage heights of the streams.

In the spring of 1913 it became apparent that the Kau ditch project would not soon be completed, and this fact, coupled with the high cost of obtaining the unsatisfactory and meager data on surface fluctuation, led to the suspension of the work until funds would be available to construct a dry trail across the entire district, to establish water-stage recorders on the larger streams, and to improve cross sections, controls, and other features. The work was suspended on July 18, 1913.

Ten rain gages read at monthly and bimonthly periods were established at approximately 500-foot elevation intervals from sea level to 5,000 feet, the approximate elevation at which the wet, or forest, zone meets the arid lava slopes of Mauna Kea Mountain. Practically all rainfall above the 5,000-foot contour is absorbed by the porous lava. Rainfall observations were terminated on June 30, 1913.

HILO GROUP.

STATIONS AT 2,700-FOOT LEVEL.

Location.—On trail in forest back of Hilo, at approximately 2,700 feet above sea level. The trail is about 8 miles long and the camp, about midway on the trail, is reached by a foot trail 3½ miles long from the end of the Kaiwiki homestead road. The camp is about 7 miles west-northwest from Hilo. Beginning at the South Branch of Wailuku River, the stations are numbered from 1 to 18 and from 25 to 87, including stations Nos. 12a and 86a, to the North Branch of Kawainui River. There are no stations numbered 19 to 24.

Records available.—Stations 1–12, October 6, 1911, to July 18, 1913. Station 12a, November 30, 1912, to July 18, 1913. Stations 13–18, 25–27, October 5, 1911, to July 18, 1913. Stations 28–41, September 28, 1911, to July 18, 1913. Stations 42–47, September 28, 1911, to July 18, 1913. Stations 48–50, September 31, 1911, to July 18, 1913. Stations 51–52, October 7, 1911, to July 18, 1913. Stations

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53–65, October 10, 1911, to July 19, 1913. Stations 66–68, October 21, 1911, to July 18, 1913. Stations 69–74, November 13, 1911, to July 18, 1913. Stations 75–86, November 14, 1911, to July 18, 1913. Station 86a, November 18, 1912, to July 18, 1913. Station 87, November 14, 1911, to July 18, 1913.

Drainage area.—About 75 square miles for all stations (may be in error 20 per cent).

Gages.—Vertical staff read to nearest two-hundredths, twice daily, about 4 days in the week.

Diversions.—All low-water run-off is diverted below the stations, but it is estimated that less than 20 per cent of the mean discharge is being utilized; no diversions above the stations.

Accuracy.—At only 24 of the 83 stations maintained is the discharge sufficient to warrant current-meter measurements and ratings; mean discharge at each of the other 59 stations is one-half second-foot or less; the aggregate mean run-off of these 59 stations for the period January 1 to June 18, 1913, is estimated to have been only 4.2 second-feet. As the mean discharge of the 24 streams rated was 194.0 second-feet, the mean run-off for the 59 estimated stations was less than 2 per cent of the total. For these stations for which ratings have been made and results published rating curves are all fairly well defined for low and medium stages. Discharge for days for which there are no gage-height records was estimated from daily rainfall records at camp near station No. 51.

The total mean run-off for all stations for the period January 1 to July 18, 1913, was 198.2 second-feet. The minimum run-off, which was less than 6 second-feet, occurred in March. The maximum run-off of all stations probably exceeded 5,000 second-feet.

Discharge measurements made at unrated stations on 2,700-foot level near Hilo, Hawaii, during the period Jan. 1 to July 18, 1913.

[E. O. Christiansen, hydrographer.]

Station No.	Date.	Gage height.	Discharge.	Station No.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
39	Apr. 24	0.90	0.23	50 [a]	May 15	2.36	0.21
	May 16	.96	.44		...do.....	2.38	.23
41	Apr. 24	.49	.80		...do.....	2.39	.25
	May 16	1.00	2.4		May 21	2.19	.04
49	Apr. 23	.93	.83		May 22	2.18	.03
50 [a]	May 4	2.38	1.22		...do.....	2.17	.03
	...do.....	2.28	.12		May 23	2.16	.03
	May 14	2.22	.06		May 24	2.14	.02
	...do.....	2.24	.08		May 29	2.24	.07
	...do.....	2.28	.11		May 30	2.20	.05
	May 15	2.23	.07		May 31	2.25	.08
	...do.....	2.26	.10	55	Apr. 18	1.22	1.03
	...do.....	2.28	.12	59	...do.....	.81	.77
	...do.....	2.30	.12	70	...do.....	.99	1.19
	...do.....	2.32	.13	73	...do.....	.90	.48
	...do.....	2.34	.18				

[a] All measurements on station No. 50 made by the volumetric method.

Discharge measurements of station No. 1 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 29	0.05	6.5
May 24	−.50	.96

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Monthly discharge of station No. 1 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	48	11	19.4	1,190	D.
February	12	(a)	3.63	130	D.
March	.2	(a)	.07	1	D.
April	160	.1	18.6	1,110	D.
May	28	.4	5.14	316	D.
June	146	.6	25.9	1,540	D.
July 1-18	60	9.0	29.5	1,050	D.
The period				5,340	

[a] No flow.

Discharge measurements of station No. 3 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 29	0.40	7.02
May 24	.11	3.16

Monthly discharge of station No. 3 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	15	7.0	10.0	615	D.
February	5.5	(a)	.75	42	D.
March	5.8	(a)	1.74	107	D.
April	68	4.7	13.4	797	D.
May	11	2.5	4.70	289	D.
June	53	2.9	11.8	702	D.
July 1-18	32	2.7	13.4	477	D.
The period				3,030	

[a] No flow.

Discharge measurements of station No. 12 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 29	1.18	7.5
May 24	.99	2.8

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Monthly discharge of station No. 12 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	34	2.8	12.5	769	D.
February	2.8	.3	1.03	57	D.
March	6.1	.3	1.47	90	D.
April	63	3.0	12.0	714	D.
May	6.1	2.0	3.48	214	D.
June	57	2.3	10.9	649	D.
July 1-18	53	2.2	13.3	474	D.
The period				2,970	

Discharge measurements of station No. 13 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 29	1.05	9.2
May 24	.74	2.25

Monthly discharge of station No. 13 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	38	4.5	12.8	787	D.
February	3.9	.2	1.09	60	D.
March	11	(a)	2.94	181	D.
April	54	5.1	12.8	762	D.
May	9.4	2.1	4.62	284	D.
June	47	3.2	11.3	672	D.
July 1-18	44	1.9	13.6	483	D.
The period				3,230	

[a] No flow.

Discharge measurements of station No. 15 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 29	1.26	3.4
May 24	1.10	.64

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Monthly discharge of station No. 15 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	17	0.7	5.78	355	D.
February	.5	.2	.37	20	D.
March	4.0	(a)	.74	46	D.
April	58	1.4	9.57	569	D.
May	3.3	.7	1.31	81	D.
June	25	.8	4.70	280	D.
July 1-18	29	.6	6.69	238	D.
The period				1,590	

a No flow.

Discharge measurements of station No. 27 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 24	1.63	4.1
May 16	1.81	8.4

Monthly discharge of station No. 27 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	30	2.3	7.93	488	D.
February	2.3	.4	1.00	56	D.
March	4.0	.2	1.62	100	D.
April	48	2.9	8.61	512	D.
May	6.2	1.2	2.70	166	D.
June	41	1.8	8.33	496	D.
July 1-18	38	1.8	1.02	365	D.
The period				2,180	

Discharge measurements of station No. 28 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 24	0.90	10.0
May 16	1.85	41.5

Monthly discharge of station No. 28 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	176	8.0	60.7	3,730	D.
February	6.0	.1	2.45	136	D.
March	9.8	(a)	1.27	78	D.
April	181	2.0	26.5	1,580	D.
May	14	.4	3.06	188	D.
June	135	1.0	19.7	1,170	D.
July 1-18	90	.3	22.0	785	D.
The period				7,670	

a No flow.

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Discharge measurements of station No. 31 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 24	0.80	4.76
May 16	1.05	9.44

Monthly discharge of station No. 31 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	52	2.6	14.0	861	D.
February	2.5	.2	.76	42	D.
March	17	(a)	2.23	137	D.
April	115	3.2	18.0	1,070	D.
May	8.5	1.1	2.94	181	D.
June	34	1.7	8.05	479	D.
July 1-18	50	.9	11.2	402	D.
The period				3,170	

a No flow.

Discharge measurements of station No. 34 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 24	1.07	6.90
May 16	1.14	1.90

Monthly discharge of station No. 34 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	16	0.2	2.51	154	D.
February	.6	.2	.27	15.0	D.
March	2.6	.2	.47	28.9	D.
April	24	.6	3.63	216	D.
May	1.3	.3	.63	38.7	D.
June	7.1	.4	1.35	80.3	D.
July 1-18	10	.3	2.12	75.6	D.
The period				608	

Discharge measurements of station No. 46 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 24	1.62	9.6
May 15	1.72	13.6

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Monthly discharge of station No. 46 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	195	5.8	56.4	3,470	D.
February	4.4	(a)	1.49	83	D.
March	16	(a)	2.85	175	D.
April	188	6.1	32.4	1,930	D.
May	46	3.0	9.47	582	D.
June	104	4.4	21.7	1,290	D.
July 1-18	82	2.5	25.4	907	D.
The period				8,440	

a No flow.

Discharge measurements of station No. 47 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 24	1.88	3.6
May 15	1.80	3.0

Monthly discharge of station No. 47 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	42	1.9	10.6	652	D.
February	1.3	.3	.68	38	D.
March	7.0	.2	1.44	88	D.
April	25	2.1	5.51	328	D.
May	5.3	1.2	2.35	144	D.
June	15	1.4	5.00	298	D.
July 1-18	17	1.7	6.29	224	D.
The period				1,770	

Discharge measurements of station No. 52 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	1.06	21.2
May 21	.81	11.8

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Monthly discharge of station No. 52 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	582	6.2	93.8	5,770	D.
February	7.6	1.1	3.57	198	D.
March	48	.4	10.1	621	D.
April	219	16	50.1	2,980	D.
May	74	6.6	17.8	1,090	D.
June	342	8.9	52.6	3,130	D.
July 1-18	155	7.4	49.5	1,760	D.
The period				15,500	

Discharge measurements of station No. 54 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 18	0.89	1.63

Monthly discharge of station No. 54 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	44	0.2	7.39	454	D.
February	.5	(a)	.13	7	D.
March	13	(a)	1.32	81	D.
April	28	1.5	5.88	350	D.
May	3.4	.2	.80	49	D.
June	14	.1	2.67	159	D.
July 1-18	18	(a)	3.50	125	D.
The period				1,230	

[a] No flow.

Discharge measurements of station No. 62 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 18	1.39	8.6
May 22	1.09	2.2

Monthly discharge of station No. 62 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	128	1.1	24.6	1,510	D.
February	2.2	(a)	9.95	553	D.
March	39	(a)	4.67	287	D.
April	100	5.3	20.5	1,220	D.
May	14	1.5	3.82	235	D.
June	42	1.8	11.0	655	D.
July 1-18	61	1.3	14.2	505	D.
The period				4,960	

[a] No flow.

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Discharge measurements of station No. 68 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 18	1.58	11.0
May 22	.98	3.1

Monthly discharge of station No. 68 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	42	1.9	15.3	941	D.
February	3.8	.8	1.76	98	D.
March	26	.5	5.37	330	D.
April	52	7.2	17.3	1,030	D.
May	17	2.2	6.02	370	D.
June	29	3.0	11.5	684	D.
July 1-18	47	2.1	13.3	474	D.
The period				3,930	

Discharge measurements of station No. 69 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 18	0.84	4.3
May 22	.70	1.2

Monthly discharge of station No. 69 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	11	0.6	5.25	323	D.
February	1.7	.3	.60	33	D.
March	10	.2	1.85	114	D.
April	22	2.8	7.13	424	D.
May	3.8	.8	1.68	103	D.
June	10	1.2	3.70	220	D.
July 1-18	17	1.1	4.65	166	D.
The period				1,380	

Discharge measurements of station No. 74 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 18	2.06	12.5
May 22	1.71	4.0

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Monthly discharge of station No. 74 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	46	2.9	18.2	1,120	D.
February	4.7	.8	2.00	111	D.
March	23	.4	5.46	336	D.
April	52	1.1	16.9	1,010	D.
May	24	3.1	7.80	480	D.
June	62	4.1	14.1	839	D.
July 1-18	56	3.1	16.5	589	D.
The period				4,480	

Discharge measurements of station No. 76 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	1.01	1.86

Monthly discharge of station No. 76 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	10	0.6	3.90	240	D.
February	1.0	.3	.48	26.6	D.
March	7.8	.2	1.15	70.7	D.
April	9.3	1.0	2.60	155	D.
May	2.0	.6	.98	60.3	D.
June	8.7	.7	1.96	117	D.
July 1-18	15	.5	2.32	82.8	D.
The period				752	

Discharge measurements of station No. 79 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	0.93	0.83

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Monthly discharge of station No. 79 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	2.5	0.2	1.06	65.2	D.
February	.2	.1	.15	8.3	D.
March	2.3	.1	.37	22.8	D.
April	3.2	.1	1.08	64.3	D.
May	.9	.2	.37	22.8	D.
June	2.4	.2	.75	44.6	D.
July 1-18	3.7	.2	.93	33.2	D.
The period				261	

Discharge measurements of station No. 80 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	1.22	1.71
May 22	.87	.52

Monthly discharge of station No. 80 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	3.6	0.5	2.04	125	D.
February	.6	(a)	.38	21.1	D.
March	3.7	(a)	.67	41.2	D.
April	4.0	1.0	2.30	137	D.
May	1.6	.4	.81	49.8	D.
June	3.6	.5	1.52	90.4	D.
July 1-18	4.5	.4	1.81	64.5	D.
The period				529	

a No flow.

Discharge measurements of station No. 81 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	1.00	4.1
May 23	.69	1.9

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Monthly discharge of station No. 81 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	12	1.0	5.98	368	D.
February	1.4	.2	.59	33	D.
March	11	.1	2.19	135	D.
April	15	3.3	7.01	417	D.
May	7.0	1.0	2.44	150	D.
June	21	1.3	7.80	464	D.
July 1-18	38	3.3	11.2	390	D.
The period				1,970	

Discharge measurements of station No. 85 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	0.88	1.90
May 23	.79	.77

Monthly discharge of station No. 85 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	6.9	1.7	4.07	250	D.
February	3.0	.7	1.37	76	D.
March	7.5	.6	2.09	129	D.
April	13	1.6	4.78	284	D.
May	2.8	.5	1.06	65	D.
June	7.3	.6	2.37	141	D.
July 1-18	14	.6	3.68	131	D.
The period				1,080	

Discharge measurements of station No. 86 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Apr. 23	1.70	5.1
May 23	1.56	1.6

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Monthly discharge of station No. 86 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	12	2.3	6.93	426	D.
February	3.2	.5	1.58	88	D.
March	12	.1	2.81	173	D.
April	19	4.0	8.07	480	D.
May	9.3	1.4	2.76	170	D.
June	19	1.7	5.66	337	D.
July 1–18	20	1.7	6.79	242	D.
The period				1,920	

Discharge measurements of station No. 87 at 2,700-foot level near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
April 23	1.30	1.39
May 23	1.04	.91

Monthly discharge of station No. 87 at 2,700-foot level near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	5.5	0.7	2.80	172	D.
February	2.2	.4	.74	41	D.
March	4.7	.3	1.19	73	D.
April	7.9	1.8	3.77	224	D.
May	3.8	.7	1.61	99	D.
June	8.1	1.0	2.93	174	D.
July 1–18	10	.9	3.52	126	D.
The period				909	

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WAILUKU RIVER NEAR HILO, HAWAII.

Location.—About 1½ miles west of Hilo, a short distance above Hilo Electric Light Co. intake.

Records available.—March 21, 1911, to July 21, 1913.

Gage.—Barrett & Lawrence water-stage recorder.

Control.—Probably slightly shifting.

Discharge measurements.—Made from cable.

Accuracy.—Records good for January and June; for other months only fair.

Discharge measurements of Wailuku River near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 9	8.00	708	May 6	5.68	157
Mar. 7	5.50	55.4	May 20	5.64	152
Mar. 13	5.23	32.5	June 17	7.55	523
Apr. 7	6.04	209	June 25	6.00	197
Apr. 26	6.25	254	July 7	7.54	557

Daily discharge, in second-feet, of Wailuku River near Hilo, Hawaii, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1	484	127	88	350	190	94	700
2	364	116	93	323	250	84	657
3	325	104	84	228	306	100	568
4	265	91	71	165	254	97	479
5	225	87	66	133	187	87	364
6	195	84	62	201	155	76	855
7	187	89	122	216	134	72	614
8	1,290	84	98	148	116	78	426
9	1,040	78	84	171	112	80	316
10	1,250	69	70	187	106	76	264
11	3,350	64	69	140	94	69	222
12	1,170	60	53	511	85	73	206
13	2,100	52	107	1,620	82	9,400	206
14	3,090	48	104	3,110	103	6,140	162
15	3,700	44	57	834	139	3,110	139
16	1,620	58	41	630	426	1,260	117
17	1,200	84	43	484	250	568	107
18	814	62	95	378	325	403	97
19	1,630	50	127	314	200	314	88
20	1,450	48	80	264	150	254	85
21	1,400	44	59	254	121	203	101
22	1,180	38	140	269	98	175	.....
23	700	38	166	236	84	158	.....
24	525	35	84	203	84	219	.....
25	418	34	66	275	84	203	.....
26	347	34	55	245	82	180	.....
27	283	33	50	348	79	139	.....
28	236	54	203	273	78	127	.....
29	203	.....	219	228	79	152	.....
30	172	.....	145	211	78	187	.....
31	145	.....	568	.....	78	.....	.....

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Monthly discharge of Wailuku River near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	3,700	145	1,010	62,100	A.
February	127	33	64.6	3,590	C.
March	568	41	109	6,700	B.
April	3,110	133	432	25,700	B.
May	426	78	149	9,160	B.
June	9,400	69	806	48,000	A.
July 1-21	855	85	322	13,400	B.
The period				169,000	

HONOLII RIVER AT KAIWIKI, NEAR HILO, HAWAII.

Location.—About one-half mile north of Kaiwiki and 6 miles west of Hilo.
Records available.—June 1, 1911, to March 24, 1913.
Gage.—Barrett & Lawrence water-stage recorder.
Control.—Probably slightly shifting.
Discharge measurements.—Made from footbridge.
Accuracy.—Records good.

Discharge measurements of Honolii River at Kaiwiki, near Hilo, Hawaii, in 1913.

[E. O. Christiansen, hydrographer.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Jan. 31	5.10	18.1
May 31	5.11	19.4

Daily discharge, in second-feet, of Honolii River at Kaiwiki, near Hilo, Hawaii, for 1913.

Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.
1	153	16	3.4	16	238	18	12
2	86	15	3.4	17	182	40	30
3	79	12	3.0	18	155	18	86
4	56	11	3.0	19	358	14	110
5	43	11	2.8	20	318	11	37
6	42	16	2.8	21	268	9.4	23
7	48	30	8.6	22	202	9.0	103
8	430	17	6.2	23	108	7.0	80
9	315	13	3.8	24	83	7.0	35
10	299	11	2.8	25	65	7.0	.....
11	724	11	2.4	26	48	5.0	.....
12	196	11	2.0	27	38	3.0	.....
13	512	10	1.8	28	32	3.0	.....
14	840	8.6	2.0	29	27	.....	.....
15	660	8.6	18	30	24	.....	.....
				31	17	.....	.....

Monthly discharge of Honolii River at Kaiwiki, near Hilo, Hawaii, for 1913.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	842	17	214	13,200
February	50	3.0	12.6	700
March 1-24	110	1.8	24.2	1,150

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HAMAKUA GROUP.

HAMAKUA DITCH AT MAIN WEIR, PUUALALA, NEAR WAIMEA, HAWAII.

Location.—Near head of ditch in Lalakea tract, adjacent to forest reserve and close to Kaala Mountain and Pacific Sugar Mill fence. This ditch diverts all run-off from upper headwaters of Waipio.

Records available.—January 1 to December 31, 1913.

Gage.—Water-stage recorder.

Discharge.—Measured by weir consisting of two 5-foot panels, sharp crested, and with good stilling basin above.

Discharge, in million gallons per day, of Hamakua ditch at main weir, at Puualala Waimea, Hawaii, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.35	1.07	0.96	8.42	2.21	2.09	18.3	1.05	2.66	0.37	.....	1.25
2	2.11	.87	.68	7.62	3.84	6.24	16.5	11.8	9.14	.30	.....	.95
3	4.21	.44	.54	3.86	6.25	7.70	12.7	11.0	10.2	.22	29.2	1.06
4	2.89	.32	.39	6.72	5.54	2.55	13.4	2.73	5.76	.18	22.7	5.06
5	2.53	.24	.32	3.42	2.94	1.53	8.78	1.39	2.30	.15	8.51	25.3
6	1.45	12.1	.26	5.09	1.56	1.14	26.8	.85	1.79	.23	3.24	19.8
7	1.04	11.0	.26	8.37	.93	1.75	20.9	.64	16.2	.32	1.68	9.33
8	.85	2.66	.20	2.80	.64	4.45	18.5	.64	5.75	.99	.98	4.55
9	1.04	1.45	.18	9.15	.61	4.96	8.55	1.31	2.50	1.32	18.7	3.50
10	3.70	.83	.18	8.02	.52	7.32	6.91	1.45	12.2	.74	20.6	2.27
11	2.66	.65	.13	20.5	.44	3.99	9.86	7.51	7.36	.37	16.1	1.60
12	1.67	.52	.13	24.9	6.21	12.7	16.2	21.3	11.6	.13	22.1	1.91
13	23.0	.39	.04	22.9	11.1	25.2	16.8	21.2	9.53	.13	17.1	1.47
14	24.6	4.26	5.61	15.6	3.72	20.5	13.8	11.3	3.61	.71	10.0	4.11
15	18.8	4.89	2.34	10.4	12.0	24.8	8.93	19.0	3.52	2.88	6.32	24.6
16	6.38	1.46	5.78	10.6	17.0	16.9	8.73	6.85	1.69	6.26	18.5	17.1
17	2.84	7.49	8.78	10.5	10.7	12.5	12.7	2.77	3.87	1.71	24.9	14.8
18	1.56	10.9	4.43	10.7	12.8	4.45	11.0	1.57	14.8	.60	30.0	13.5
19	1.26	20.6	4.97	8.41	17.9	2.90	5.16	1.08	9.65	.24	15.0	6.56
20	.95	10.4	2.94	5.03	6.59	2.25	6.08	.83	5.27	1.60	12.3	3.21
21	.74	10.2	11.9	4.36	2.64	1.62	10.1	.92	2.79	2.50	13.5	2.03
22	1.11	8.62	16.7	5.74	1.53	1.37	15.7	1.45	1.32	1.34	13.2	1.56
23	.95	3.54	4.78	7.46	1.42	6.43	6.47	.95	.68	1.87	9.60	13.3
24	.68	1.55	3.37	5.95	1.57	8.64	3.70	1.16	.52	.95	14.1	4.13
25	.68	2.58	4.06	8.01	2.68	3.94	3.40	1.14	.61	.37	14.6	1.79
26	.40	13.8	2.40	4.65	20.3	6.67	6.45	.68	.60	.15	12.5	1.25
27	.46	3.12	4.43	7.22	13.6	23.4	2.84	.62	.30	.86	10.3	.85
28	.55	1.37	24.6	8.02	18.3	27.5	5.28	1.20	.26	.56	3.90	.70
29	.37	.....	11.1	3.82	13.7	23.4	3.04	2.74	.32	.....	2.00	.52
30	.30	.....	13.9	2.58	6.22	22.3	1.68	10.7	.30	.....	1.68	.40
31	.24	.....	16.2	.....	3.60	.....	1.45	5.04	.....	.....	.....	.30

NOTE.—No discharge Oct. 29 to Nov. 2.

Monthly discharge of Hamakua ditch at main weir, Puualala, Waimea, Hawaii, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	24.6	0.24	3.66	348
February	20.6	.24	4.90	422
March	24.6	.04	4.92	468
April	24.9	2.58	8.69	800
May	20.3	.44	6.74	641
June	27.5	1.14	9.70	893
July	26.8	1.45	10.3	980
August	21.3	.62	4.93	469
September	16.2	.26	4.90	451
October 1-28	6.26	.13	1.00	86
November 3-30	30.0	.98	13.3	1,140
December	25.3	.30	6.09	579
The period	.....	.....	.....	7,300

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NEW HAMAKUA DITCH AT MAIN WEIR NEAR KUKUIHAELE, HAWAII.

Location.—Near head of ditch, about 500 feet south of office of Hawaiian Irrigation Co. (Ltd.), at Kukuihaele.

Records available.—July 18, 1910, to December 31, 1913.

Gage.—Water-stage recorder.

Discharge.—Measured by weir consisting of six 5-foot panels, sharp crested, and with a good stilling basin above. Discharge measurements made in ditch below weir have checked weir discharge to within 2 per cent.

Diversion.—Ditch diverts all run-off from headwaters of Waipio basin below the upper Hamakua ditch.

Cooperation.—Daily-discharge record furnished by the Hawaiian Irrigation Co. (Ltd.).

Discharge, in million gallons per day, of New Hamakua ditch at main weir, Kukuihaele, Hawaii, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	32.3	27.1	26.7	34.6	29.1	28.7	41.4	26.0	28.6	25.7	23.9	30.6
2	30.5	27.3	26.3	33.1	32.3	30.7	42.2	32.3	32.7	25.2	23.7	30.2
3	31.1	25.5	26.0	30.7	34.0	32.9	38.5	37.2	41.5	25.0	43.8	30.1
4	30.9	26.0	26.0	31.5	32.1	29.3	38.9	30.4	34.0	24.9	41.5	32.1
5	30.7	25.9	25.9	29.6	29.7	27.5	33.4	27.5	30.4	24.8	38.2	34.2
6	29.9	31.5	25.6	29.1	27.9	26.9	42.0	26.7	29.4	25.3	33.4	33.7
7	29.3	34.9	25.5	32.8	27.3	27.5	42.0	26.2	42.7	25.1	30.9	34.0
8	28.7	30.0	25.3	28.9	26.8	28.9	42.0	27.6	34.2	25.1	29.7	34.0
9	28.7	27.9	25.4	31.3	26.2	28.9	38.9	28.1	30.8	25.2	34.7	34.0
10	30.3	26.6	24.8	32.9	26.2	29.9	36.6	28.1	39.2	24.6	34.2	34.0
11	29.5	26.7	24.8	34.1	25.6	27.5	36.5	31.5	35.9	24.6	33.9	32.7
12	28.7	26.6	24.7	34.9	27.9	30.4	42.2	43.5	38.5	24.6	34.2	33.3
13	33.6	25.8	24.6	34.7	33.4	34.1	42.0	51.7	38.1	24.6	34.0	32.2
14	34.8	27.9	26.2	34.1	29.1	34.4	40.9	41.4	31.0	26.0	34.2	32.2
15	34.8	29.6	26.1	34.8	31.3	34.4	36.1	52.1	29.8	28.5	33.6	34.4
16	34.6	26.9	26.9	34.8	33.0	34.4	44.2	37.2	28.4	30.9	34.7	34.8
17	32.1	29.4	32.5	34.7	35.4	34.2	38.7	32.5	28.8	27.0	34.7	34.2
18	30.5	33.9	28.2	34.1	33.7	32.3	38.8	30.3	43.1	25.4	33.8	34.0
19	29.9	35.0	27.9	34.1	34.6	30.3	33.6	29.0	38.9	24.3	34.2	34.0
20	28.7	34.1	26.1	33.7	32.7	29.4	34.4	28.9	31.7	26.1	34.4	34.2
21	29.0	34.3	29.7	33.3	29.1	28.3	36.3	12.9	29.4	29.1	34.3	33.1
22	29.5	34.2	37.0	34.7	27.3	27.7	40.1	29.2	27.8	26.3	34.0	32.1
23	29.0	29.8	30.2	34.1	28.3	29.7	34.9	28.5	27.0	26.8	34.9	34.0
24	28.1	28.3	27.5	33.4	28.5	33.1	31.7	29.0	26.2	25.9	34.6	33.5
25	27.9	27.0	29.8	32.6	27.9	29.2	30.7	28.3	26.0	24.8	34.0	32.0
26	26.4	33.0	27.1	32.3	35.2	29.3	33.0	27.7	25.8	24.2	34.1	31.3
27	26.6	28.6	27.2	33.9	35.2	34.6	30.0	27.7	25.8	24.6	34.4	30.9
28	26.9	27.4	35.7	34.0	34.6	34.4	31.1	27.9	25.6	24.8	33.8	30.5
29	26.1	.....	35.8	31.5	34.6	34.4	29.7	30.1	25.5	24.2	32.0	30.1
30	26.0	.....	34.7	30.2	31.3	34.2	28.8	34.7	25.5	23.9	31.2	29.6
31	25.7	.....	36.1	.....	29.9	.....	28.0	31.9	.....	23.9	.....	29.0

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Monthly discharge of New Hamakua ditch at main weir, near Kukuihaele, Hawaii, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	34.8	25.7	29.7	2,830	A.
February	35.0	25.5	29.3	2,520	A.
March	37.0	24.6	28.3	2,692	A.
April	34.9	28.9	33.0	3,040	A.
May	35.4	26.2	30.7	2,920	A.
June	34.6	26.9	30.9	2,840	A.
July	44.2	28.0	36.7	3,490	A.
August	52.1	12.9	31.5	3,000	A.
September	43.1	25.5	31.7	2,920	A.
October	30.9	23.9	25.5	2,430	A.
November	43.8	23.7	33.8	3,110	A.
December	34.8	29.0	32.5	3,090	A.
The year	52.1	12.9	31.1	34,900	

KOHALA GROUP.

KOHALA DITCH NEAR KOHALA, HAWAII.

Location of weirs.—The Kohala Ditch Co. (Ltd.) maintains three weirs which measure the discharge carried by the Kohala ditch. The Awini weir is on the southeast side of the east branch of Honokanenui Gulch at an elevation of 1,880 feet. The Niulii weir is about 3½ miles south of Niulii, Kohala district, at an elevation of 1,000 feet, and about 5 miles below the Awini weir. The Hawi weir is about 1½ miles south of the Hawi mill near the lower end of the ditch.

Records available.—Daily records at Awini and Niulii weirs kept by Kohala Ditch Co. July 1, 1907, to December 31, 1913. No record of flow at Hawi weir, which has been used mainly as a check on deliveries of water between Niulii and Hawi. The Niulii weir measures the amount of water shown by the Awini weir and also the inflow from the Honokanenui. The record for the Honokenenui is derived by subtracting the flow at the Awini weir from the flow at the Niulii weir.

Gages.—Vertical staffs graduated to hundredths.

Discharge measurements.—Each weir consists of three 5-foot panels with end contractions, sharp-beveled steel crest, and with very slight velocity of approach.

Diversion.—Ditch diverts and delivers to the plantations on the north coast of Hawaii all low-water run-off between the Honokane Gulch and the northwest point of the island below the 2,000-foot contour.

Cooperation.—Daily-discharge record furnished by Kohala Ditch Co. (Ltd.).

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Discharge, in million gallons per day, of Kohala ditch at Awini weir, near Kohala, Hawaii, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	12.5	9.3	4.8	12.5	7.5	2.3	16.9	3.3	5.2	0.9	.....	6.6
2	11.0	9.8	4.0	11.5	8.8	.....	19.5	4.4	3.7	.9	.....	9.8
3	11.0	7.9	3.3	8.4	8.8	2.1	16.9	8.4	4.8	.9	11.5	9.8
4	10.5	5.2	3.7	6.2	7.5	6.2	14.6	6.2	4.8	.9	18.3	10.5
5	11.0	4.4	3.7	6.2	7.5	6.2	12.5	5.8	3.7	.5	13.6	20.7
6	10.5	10.5	3.7	7.5	7.0	4.0	20.7	5.2	3.0	.5	10.5	20.7
7	8.8	14.1	3.7	9.3	6.6	4.8	20.7	4.0	6.2	.5	7.0	20.7
8	9.8	9.8	3.7	6.2	5.2	5.8	16.9	4.0	6.2	1.5	5.2	20.7
9	10.5	7.9	3.3	5.2	4.4	5.8	14.6	3.3	5.2	1.2	20.1	20.1
10	12.5	4.4	3.0	7.5	4.4	5.8	12.0	4.0	6.2	2.1	20.1	19.5
11	10.5	4.4	2.7	12.5	4.4	5.2	10.5	4.0	7.9	1.5	20.1	16.9
12	10.5	3.3	2.7	15.7	6.6	5.2	14.6	16.9	7.0	.9	20.1	14.1
13	20.7	3.3	2.4	15.7	15.7	20.7	16.9	20.7	7.9	.7	15.2	12.5
14	20.7	9.3	2.4	15.7	15.7	20.7	14.6	20.7	6.2	.5	12.0	11.5
15	20.7	8.4	2.7	15.7	15.7	20.7	14.6	16.9	4.8	.5	10.5	20.7
16	13.0	6.6	2.7	15.7	14.6	16.3	12.5	15.2	4.0	1.5	12.0	20.7
17	12.5	11.0	2.7	14.6	14.6	13.6	10.5	12.5	3.7	1.2	20.1	20.7
18	11.0	11.5	3.3	15.7	11.5	9.8	8.4	7.5	7.9	.9	20.1	20.7
19	9.8	14.1	3.3	14.6	10.5	9.3	8.4	5.8	11.5	.7	20.1	16.9
20	9.8	11.5	3.3	14.6	8.8	6.6	7.5	4.8	7.0	.5	16.3	14.1
21	8.4	8.8	7.5	12.5	7.5	6.6	6.6	4.8	5.2	.5	20.1	12.5
22	8.4	8.8	12.5	11.5	6.2	5.2	7.9	4.0	4.4	.5	14.6	10.5
23	7.9	8.4	7.9	12.0	4.4	4.8	7.5	3.3	3.3	.5	13.6	15.7
24	7.9	6 6	4 8	9.8	4.0	5.2	6.6	2.7	2.7	.5	13.6	14.1
25	5.2	6.6	4.0	10.5	4.0	4.8	5.8	4.0	1.8	.5	12.5	12.5
26	5.2	14.1	4.0	9.8	12.0	4.8	6.2	2.1	1.8	.5	12.5	10.5
27	5.2	8.4	3.3	14.6	15.7	14.6	5.8	2.1	1.8	.3	11.0	9.8
28	4.8	6.6	12.0	13.0	12.0	20.7	5.8	2.1	1.2	.2	9.8	7.9
29	4.8	.....	10.5	10.5	13.6	20.7	5.2	2.1	1.2	.....	8.4	6.6
30	4.8	.....	7.5	9.3	10.5	20.7	4.4	5.8	1.2	.....	7.5	6.2
31	4.8	.....	12.5	.....	7.5	.....	4.4	5.8	.....	.....	.....	6.2

NOTE.—No record June 2, Oct. 29 to Nov. 2.

Monthly discharge of Kohala ditch at Awini weir, near Kohala, Hawaii, for 1913.

Month.	Discharge in million gallons per per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	20.7	4.8	10.1	961
February	14.1	3.3	8.39	721
March	12.5	2.4	4.89	465
April	15.7	5.2	11.5	1,060
May	15.7	4.0	9.14	870
June 1, 3–30	20.7	2.1	9.63	857
July	20.7	4.4	11.3	1,080
August	20.7	2.1	6.85	652
September	11.5	1.2	4.72	435
October 1–28	2.1	.2	.80	69
November 3–30	20.1	5.2	14.2	1,220
December	20.7	6.2	14.2	1,340
The period	.....	.....	.....	9,730

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Discharge, in million gallons per day, of Kohala ditch at Nuilii weir, near Kohala, Hawaii, for 1913.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	12.8	11.1	9.2	12.8	11.3	6.3	10.6	9.9	9.5	6.8	6.0	9.9
2	12.6	11.4	9.2	12.1	13.1	.....	8.0	10.2	8.2	6.3	6.0	13.0
3	12.6	10.1	8.5	11.2	13.1	4.0	10.6	12.0	8.5	6.3	14.7	12.2
4	11.5	10.6	8.9	11.8	11.3	11.1	12.8	11.8	8.5	6.8	9.1	13.1
5	12.6	10.3	8.9	11.8	11.3	11.1	14.9	11.5	8.2	7.3	13.9	6.8
6	11.5	13.9	8.9	11.3	11.0	9.9	6.8	10.6	8.2	7.3	10.6	6.8
7	9.9	13.3	8.9	11.1	10.6	9.9	6.8	9.2	10.3	6.7	9.5	6.8
8	10.6	11.4	8.9	9.6	10.6	10.0	10.6	9.2	11.1	7.1	8.1	6.8
9	12.3	10.1	8.5	9.5	10.3	10.0	12.8	9.2	10.6	7.4	6.1	7.4
10	13.6	10.3	8.2	11.3	10.3	10.0	12.4	9.2	11.1	14.4	7.4	8.0
11	10.6	10.3	7.9	13.6	10.3	9.5	11.5	9.2	14.0	8.4	7.4	10.6
12	11.5	9.2	7.9	11.7	13.0	9.5	12.8	10.6	11.7	9.0	7.4	13.3
13	5.5	9.9	7.5	11.7	11.7	6.8	10.6	6.8	11.6	8.0	12.3	14.9
14	6.8	10.3	7.5	11.7	11.7	6.8	12.8	6.8	9.6	7.3	13.3	16.0
15	6.8	10.4	7.9	11.7	11.7	6.8	12.8	10.6	8.5	7.3	11.5	6.8
16	13.1	10.6	7.9	11.7	12.8	11.1	10.3	12.3	7.8	6.2	11.6	6.8
17	11.9	12.6	7.9	12.8	12.8	13.9	11.5	12.8	7.5	6.5	7.4	6.8
18	11.8	13.8	8.5	11.7	16.0	10.6	13.6	12.1	14.0	6.8	7.4	6.8
19	10.6	13.3	8.5	12.8	16.9	10.3	12.8	10.7	16.0	7.1	7.4	10.6
20	10.6	13.0	8.5	12.8	14.8	9.1	12.1	9.9	10.2	7.3	11.1	13.3
21	10.4	12.3	10.5	13.6	12.9	10.6	12.2	9.9	8.8	7.3	7.4	14.9
22	10.4	12.3	14.9	12.1	10.3	11.3	14.0	9.2	8.1	7.3	12.8	15.6
23	10.1	11.2	10.1	12.4	10.3	9.9	14.5	9.2	7.2	7.3	13.9	11.7
24	10.1	9.9	9.9	12.2	9.2	11.3	13.0	9.2	7.2	8.2	13.9	13.3
25	10.6	9.9	9.2	12.3	9.2	11.0	10.7	9.2	6.9	8.2	14.9	12.8
26	10.6	13.3	9.2	12.2	12.4	9.9	12.6	9.1	7.5	6.7	14.9	13.1
27	10.6	11.2	9.2	12.8	11.7	9.8	11.5	8.5	6.9	6.8	16.5	12.2
28	9.9	10.6	13.3	13.1	12.4	6.8	11.5	8.5	6.5	7.0	13.8	11.6
29	9.9	.....	13.1	12.3	13.9	6.8	12.1	9.1	7.4	6.6	12.8	11.4
30	9.9	.....	12.1	12.7	11.5	6.8	11.3	10.0	7.4	6.6	11.3	11.1
31	9.9	.....	15.8	.....	10.5	.....	11.3	10.0	.....	6.6	.....	11.1

NOTE.—No discharge June 2.

Monthly discharge of Kohala ditch at Nuilii weir, near Kohala, Hawaii, for 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	13.6	5.5	10.7	1,020
February	13.9	9.2	11.3	971
March	15.8	7.5	9.53	907
April	13.6	9.5	12.0	1,100
May	16.9	9.2	11.9	1,130
June 1, 3–30	13.9	4.0	9.34	831
July	14.9	6.8	11.7	1,110
August	12.8	6.8	9.89	941
September	16.0	6.5	9.30	856
October	14.4	6.2	7.38	702
November	16.5	6.0	10.7	985
December	15.6	6.8	10.8	1,030
The period (364 days)	15.8	4.0	10.4	11,600

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KEHENA DITCH AT HONOKANE MAUKA, NEAR NORTH KOHALA, HAWAII.

Location of weirs.—On 22 streams in Kehena district, beginning at head of Honokane Gulch and extending northeast about 8 miles in Kohala Mountains, at elevation of 4,200 to 3,000 feet.

Records available.—April 1, 1912, to March 31, 1913.

Gages.—Vertical staffs; read once daily.

Discharge.—Determined by means of sharp-crested weirs with end contractions.

Diversion.—Ditch diverts most of the water above 2,000-foot contour.

Cooperation.—Daily-discharge record furnished by Kohala Ditch Co. (Ltd.).

Combined daily discharge, in million gallons per day (weirs 1 to 22), of 22 streams supplying Kehena ditch at Honokane Mauka, North Kohala, Hawaii, Apr. 1, 1912, to Mar. 31, 1913.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1	34.23	5.23	0.83	2.96	0.18	0.76	7.24	9.95	25.78	2.47	0.50	0.89
2	18.65	15.10	.57	4.03	.19	33.71	2.25	2.73	7.41	1.86	.63	.71
3	54.24	7.62	.28	5.20	.23	84.81	4.99	1.87	2.90	1.50	.46	.57
4	57.50	10.81	.11	3.72	.17	170.34	3.31	1.11	2.00	2.76	.31	.43
5	25.03	19.96	.09	5.37	.15	9.33	.93	1.77	1.55	1.56	.30	.33
6	14.76	26.53	.03	3.77	.14	3.80	.31	1.68	1.26	1.04	1.22	.29
7	119.37	5.36	.03	28.23	1.29	23.61	.17	1.24	3.05	.82	5.09	.24
8	35.19	21.26	1.45	4.36	.87	5.24	.11	1.10	10.84	1.06	2.33	.19
9	41.60	11.77	16.20	11.68	22.99	2.34	.10	21.51	4.34	2.06	1.07	.18
10	28.50	5.06	11.32	3.05	20.62	1.12	.98	105.51	22.16	9.28	.68	.17
11	16.86	2.19	20.22	4.57	10.50	.77	.40	26.86	3.29	3.54	.42	.17
12	19.93	.97	6.36	3.71	18.50	.62	.22	11.95	1.93	2.05	.28	.17
13	24.98	.99	10.68	1.60	19.83	.49	.16	49.26	1.53	10.41	.16	.17
14	9.39	.92	4.78	9.04	16.82	.52	7.20	7.94	1.50	27.97	.51	.14
15	12.18	.53	3.38	2.02	27.82	.54	3.48	3.03	1.28	20.71	2.22	.14
16	6.64	.53	22.26	.73	5.10	5.90	1.48	41.31	.84	5.10	1.06	.13
17	13.27	2.39	13.94	1.42	3.04	2.50	2.86	93.77	.74	2.36	5.86	2.82
18	3.82	1.26	6.58	.92	2.42	.78	1.25	70.51	.92	1.54	7.45	2.62
19	2.04	6.05	23.12	.55	7.69	.51	7.58	39.60	1.09	.96	24.81	8.20
20	1.44	6.11	8.87	.37	2.64	.89	1.55	12.19	6.52	.74	7.87	3.54
21	3.38	18.91	13.22	.24	1.54	5.42	3.75	13.50	2.28	.59	5.86	8.42
22	5.06	3.89	4.09	.64	.75	1.50	1.34	9.02	12.86	.56	6.38	26.49
23	6.94	1.54	2.97	4.52	.28	.59	25.67	12.20	46.28	.48	3.51	7.11
24	27.08	1.14	22.09	32.66	.15	.33	33.89	5.83	21.87	.42	1.27	3.81
25	13.86	5.86	4.30	3.51	.07	.05	6.37	3.06	5.67	.38	3.99	1.23
26	31.01	1.65	1.77	2.79	.03	.05	3.99	1.72	10.78	.28	11.18	1.07
27	13.25	14.35	5.35	3.33	.14	.05	62.69	1.52	5.08	.25	4.60	1.46
28	7.23	10.02	1.63	1.46	4.90	.03	19.43	1.32	2.89	.31	2.01	37.46
29	5.95	3.93	1.17	.78	3.96	.03	23.46	7.67	6.09	.23	.....	20.86
30	12.66	4.70	7.44	.44	1.27	13.30	6.39	2.57	6.14	.15	.....	7.00
31	.....	1.84	.....	.26	.70	.....	10.56	.....	6.30	.12	.....	18.24

Combined monthly discharge of weirs Nos. 1 to 22, Kehena ditch, at Honokane Mauka, North Kohala, Hawaii, Apr. 1, 1912, to Mar. 31, 1913.

Month.	Discharge in million gallons per day.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
April	119.37	1.44	22.2	2,040
May	26.53	.53	7.05	671
June	23.12	.03	7.17	660
July	32.66	.24	4.77	454
August	27.82	.03	5.65	538
September	170.34	.03	12.3	1,130
October	62.89	.10	7.88	750
November	105.51	1.10	18.8	1,730
December	46.28	.74	7.33	697
January	27.97	.12	3.32	316
February	24.81	.16	3.65	314
March	37.46	.13	5.01	477
The year	170.34	.03	8.74	9,780

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MISCELLANEOUS MEASUREMENTS.

Measurements of streams on the island of Hawaii at points other than regular gaging stations are listed below:

Miscellaneous discharge measurements on Hawaii for 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.
			Feet.	*Sec.-ft.*
Apr. 14	Pukihae	Near Hilo	−4.51	27.5
May 28	do	do	−4.76	11.8
June 3	do	do	−4.50	29.0
July 10	do	do	−4.52	28.1
Apr. 14	Pohakunanaka	do	−3.35	5.60
May 28	do	do	−3.42	3.10
June 3	do	do	−3.27	7.85
July 10	do	do	−3.33	4.90
June 21	Upper Springs Hilo Water Supply	Piihonua, near Hilo		2.09
24	Small Springs	do		.74
July 12	do	do	.62	.75
Mar. 20	Hanawai	Near Papaikou	.36	9.9
June 28	do	do	.45	17.3
July 9	do	do	.51	28.0
June 27	Aleamai	do		14.6
July 9	do	do	−3.25	16.2
June 28	Large spring	Piihonua, near Hilo		2.54
May 8	Maili	Near Hilo	− .15	33.5
July 8	do	do	− .44	10.5
May 10	Waipahoehoe	Near Papaikou	−3.10	23.7
July 8	do	do	−2.40	62.6
May 10	Kapue	do	−4.24	30.6
July 9	do	do	3.02	52.8
11	Makoewai	Near Honomu		6.94
11	Honomu	do		10.8
11	Kapahehe	do	− .69	12.4
12	Waste from large spring	Piihonua, near Hilo	.36	.19
Jan. 8	Kawainui	Near Pepeekeo	4.00	491
Mar. 20	do	do	.98	16
June 27	do	do	(a)	27
July 9	do	do	(a)	48
Jan. 26	Waipio	Below Waima	.35	55
26	do	Below Wolawa	.79	19

a Staff gage washed out by flood.

RAIN GAGING.

The rainfall of the Hawaiian Islands is extremely variable, ranging from a few inches at several low-level, leeward localities to more than 600 inches per annum, usually at elevations above 2,000 feet and on the windward sides of the islands. Valleys lying on the same sides of the islands and within a few miles of each other may have a variation in mean annual precipitation of several hundred per cent. The rainfall may also vary greatly in the same valley for different elevations. As a rule the zones of heaviest precipitation are on the windward sides of the islands, 2,000 to 3,000 feet above sea level.

Generally the daily rain gages maintained by the United States Weather Bureau are located at low levels. Lack of funds and the absence of inhabitants at high-level localities have prevented the maintenance of Weather Bureau stations at high levels, although in a number of cases daily records are furnished that bureau by occupants and caretakers of mountain houses and ranches. The data furnished by the Weather Bureau are therefore generally of little value in their relation to stream run-off.

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When high levels have been accessible and funds available high-level rain gages, which are read monthly and bimonthly, have been established by this office and some valuable records obtained. To determine the precipitation of the Territory accurately would require the installation of thousands of gages and the construction of hundreds of miles of trails.

Acknowledgment for cooperation in furnishing rainfall data is due the following: Kauai—Kekaha Sugar Co., Makee Sugar Co., Hawaiian Sugar Co., Grove Farm Plantation, W. F. Sanborn of Princeville Ranch, Kauai Electric Co., and J. McClellan—Oahu, C. C. Bitting, F. Meyer, and Hawaii Preserving Co.; Maui—Wailuku Sugar Co., Honolulu Ranch, Hawaiian Commercial & Sugar Co., Maui Board of Supervisors, Pioneer Mill Co., and Olowalu Sugar Co.; Hawaii—Hawaii Mill Co., P. W. P. Bluett, W. S. May, C. F. Clark, C. R. Willard, Alex. Valentine, Honokaa Sugar Co., Pacific Sugar Mill, Hawaiian Irrigation Co., and Kukaiau Ranch Co.

The tables on pages 180–185 show the precipitation at stations maintained by the Geological Survey and precipitation data furnished from private sources which are not included in United States Weather Bureau records, to which those interested in further data are referred.

Rainfall stations in Hawaii.

KAUAI.

1. Kokee, on mesa one-half mile above Knudsen's camp near head of Kokee Stream and about 19 miles north of Waimea; 3,550 feet above sea level.
2. Puu Lua, near wagon road from Kekaha to Halemanu, about 12 miles north of Waimea; 3,500 feet above sea level.
3. Lehuamakanoi, about 22 miles by road and trail north of Waimea; 3,932 feet above sea level.
4. Paukahana, about 21 miles north of Waimea by road and trail; 3,723 feet above sea level.
5. Waiakoali, about 22 miles by road via Halemanu north of Waimea; 3,450 feet above sea level.
6. Kilohana, near Alakai swamp, about 23 miles by road and trail north-northeast of Waimea; 4,023 feet above sea level.
7. Mohihi, on ridge at head of Mohihi Valley and about 23 miles by road and trail northeast of Waimea; 3,500 feet above sea level.
8. Mohihi-Koaie divide, on ridge about 24 miles by road and trail north of Waimea; 3,950 feet above sea level.
9. Waialae, near Kaholuamanu; 14 miles by road and trail north of Waimea, near Waialae gaging station; 3,600 feet above sea level.
10. Hukipo, 3 miles northwest of Waimea; 400 feet above sea level; records furnished by Kekaha Sugar Co.
11. Pali trail, one-half mile mauka of Kekaha ditch where trail crosses and about 2 miles mauka from Waimea; 850 feet above sea level; records furnished by Kekaha Sugar Co.
12. Camp No. 7, about 2 miles northeast of Waimea; 150 feet above sea level; records furnished by Hawaiian Sugar Co.
13. Waimea, in Mr. J. McClellan's yard; 10 feet above sea level; Mr. McClellan aids in obtaining record.

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14. Kaholuamanu, about 12 miles by road and trail northeast of Waimea; 3,650 feet above sea level.
15. Kahana, near Halekua camp, on ridge about 16 miles by road and trail via Kaholuamanue from Waimea; 3,750 feet above sea level.
16. Keanakua, near Halekua camp, on ridge about 16 miles by road and trail north-northeast of Waimea; 4,450 feet above sea level.
17. Olokele mauka, on ridge on left side of Olokele Stream above intake of Olokele ditch, and about 18 miles by road and trail from Waimea; 2,100 feet above sea level; records furnished by Hawaiian Sugar Co.
18. Waialeale, on summit of ridge at headwaters of Hanapepe, Wainiha, Hanalei, and Olokele streams, and North and South Forks of Wailua River; about 25 miles by road and trail northeast of Waimea; 5,075 feet above sea level.
19. Camp No. 2, about 2 miles northwest of Hanapepe and 7 miles southeast of Waimea; 250 feet above sea level; records furnished by Hawaiian Sugar Co.
20. Hanapepe Valley, on left bank of Hanapepe ditch, 3 miles above Koula, and about 8 miles north of Eleele; 530 feet above sea level; records furnished by Hawaiian Sugar Co.
21. Hiloa-Manawaiopuna divide, on ridge between east and west branches of Hanapepe Stream, about 10 miles northeast of Eleele; 2,080 feet above sea level.
22. Aakukui, near plantation camp, about 5 miles southwest of Lihue; 350 feet above sea level; records furnished by Grove farm.
23. Waiahi, on South Wailua River, near Lihue Electric Co.'s power plant, 7 miles from Lihue; 600 feet above sea level.
24. Hanahanapuni, on ridge near Kauai Electric Co.'s power line, about 10 miles northwest of Lihue; 911 feet above sea level.
25. North Wailua, near Waialeale Pali, in North Kailua Valley, about 15 miles by road and trail northwest of Lihue; 1,250 feet above sea level.
26. Pohakupili, on top of narrow ridge about 6 miles west of Kealia; 2,590 feet above sea level.
27. Puu Eu, on ridge about 6½ miles west of Kealia; 2,748 feet above sea level.
28. Kaneha, at gate tender's house near the mauka Kaneha reservoir, and about 5 miles northwest of Kealia; 800 feet above sea level; records furnished by Makee Sugar Co.
29. Summit Camp (Wainiha ridge), Hanalei; about 30 feet southwest of house at Summit Camp on power line; 6 miles from Kapaka; 1,900 feet above sea level; gage read by employee of Kauai Electric Co.
30. Kapaka, at Lineman's camp, about 50 feet north of house, and 5 miles south of Hanalei; 635 feet above sea level; gage read by employee of Kauai Electric Co.
31. About 40 feet north of Sanborn's residence, 2 miles from Hanalei; 105 feet above sea level; records furnished by Princeville ranch.
32. About 50 feet below Kauai Electric Co.'s power house, at tailrace, 7 miles west of Hanalei; 125 feet above sea level; records furnished by Kauai Electric Co.
33. Intake of Wainiha Power Co.'s canal, 6 miles back of Hanalei; 700 feet above sea level; records furnished by Kauai Electric Co.

OAHU.

1. Nuuanu Pali, on the water reservation, near the Pali road, about 200 yards toward Honolulu from top of the Pali; 1,200 feet above sea level.
2. Summit of Konahuanui, southeast of Nuuanu Pali, about 6 miles in air line northeast of Honolulu; 3,100 feet above sea level.
3. Near summit of Mount Olympus, back of Manoa Valley, about 6½ miles in air line northeast of Honolulu; 2,400 feet above sea level.
4. Waiomao, on the property of C. C. Bitting, lot No. 8, Palolo Valley, Honolulu; 600 feet above sea level; records furnished by C. C. Bitting.

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5. Kaau crater, on trail from Mount Olympus, a short distance before it leads down the ridge into Palolo Valley and about 3½ miles north of Kaimuki car line; 1,700 feet above sea level.
6. On the ridge between the Waiahole and Waiawa portals of the Waiahole Water Co.'s tunnel, near Waiahole, Waikane, Oahu; 2,150 feet above sea level.
7. Makaha, near Waianae, on property of Waianae plantation; 1,300 feet above sea level; records furnished by F. Meyer, manager Waianae plantation.
8. About 150 yards downstream on left bank of North Fork of Kaukonahua stream from Waialua Agricultural Co.'s ditch intake, on trail 8 miles north of Wahiawa; 1,200 feet above sea level.
9. Near the office of the Hawaiian Preserving Co., Wahiawa; 940 feet above sea level; records are furnished by Hawaiian Preserving Co.

MAUI.

1. In H. B. Penhallow's yard, Wailuku; 390 feet above sea level; records furnished by Wailuku Sugar Co.
2. Yard at Wailuku Sugar Co.'s office, Wailuku; 175 feet above sea level; records furnished by Wailuku Sugar Co.
3. Right bank of Iao Stream at the gaging station, 20 feet from the north anchorage of the cable; 3 miles west of Wailuku; 830 feet above sea level.
4. Iao Valley on small plateau or tableland between north and south branches of Iao Stream, about 1 mile above the junction; about 4 miles west of Wailuku; 1,500 feet above sea level.
5. About 1,000 feet below small cave in Iao Valley, on ridge between north and south branches of Iao Stream; about 5½ miles west of Wailuku; 1,720 feet above sea level.
6. Waiehu, at T. Burlem's house on old Spreckels ditch just south of South Waiehu Gulch, 2 miles northwest of Wailuku; 200 feet above sea level; records furnished by Hawaiian Commercial & Sugar Co.
7. Waihee, on roof of building formerly used as plantation office; 3½ miles from Wailuku; 125 feet above sea level; records furnished by Wailuku Sugar Co.
8. Waihee Gulch, on right bank of the stream, about 100 feet below lower development tunnel; about 5½ miles from mouth of gulch and 3 miles above intake of Waihee canal and the Waihee gaging station; 1,500 feet above sea level.
9. Rim of extinct crater of Mount Eke; 14 miles by trail from Honokahau; 4,500 feet above sea level.
10. Honokahau Gulch at ditchman's house on left bank of stream, 150 feet below ditch intake; about 8 miles from Honokahau; 800 feet above sea level; records furnished by Honolua Ranch Co.
11. Camp on ridge between Honokahau and Kahakuloa gulches beside trail leading to top of Mount Eke; about 12 miles from Honokahau; 2,300 feet above sea level.
12. Honokahau ditch about one-half mile south of Honokahua Gulch and about 4 miles from Honokahau; 760 feet above sea level; records furnished by Honolua Ranch Co.
13. Honokawai Gulch at junction with Amalu Stream; on trestle supporting Honokawai flume about 1,000 feet below intake; about 3½ miles from Kaanapali and 7½ miles from Lahaina; 1,500 feet above sea level; records furnished by Pioneer Mill Co.
14. West slope of Puu Kukui, about one-half mile south of Honokawai Gulch; about 4½ miles east of Kaanapali and 8½ miles from Lahaina; 2,500 feet above sea level; records furnished by Pioneer Mill Co.
15. West slope of Puu Kukui at top of left bank of Honokawai Gulch; about 6 miles east of Kaanapali and 10 miles from Lahaina; 5,000 feet above sea level; records furnished by the Pioneer Mill Co.

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16. Olowalu Sugar Co.'s mill in Olowalu; 10 feet above sea level; records furnished by Olowalu Sugar Co.
17. Olowalu Gulch (mauka) on right bank of Olowalu Stream about 3½ miles north of Olowalu; 600 feet above sea level; records furnished by Olowalu Sugar Co.
18. Waikapu Gulch, on left bank of the South Branch of Waikapu Stream, about 4 miles by trail from Waikapu and 6 miles from Wailuku; 1,535 feet above sea level.
19. Olinda, on Kula pipe line; 4 miles east of Makawao; 4,000 feet above sea level; records furnished by Board of Supervisors, County of Maui.
20. Waikamoi Gulch, on Kula pipe line at reservoir; 3 miles from Olinda and 7 miles from Makawao; 4,200 feet above sea level; records furnished by Board of Supervisors, County of Maui.
21. Puohakamoa, on Kula pipe line about 1,000 feet below intake at Puohakamoa Gulch; 4 miles east of Olinda and 8 miles from Makawao; 4,300 feet above sea level; records furnished by Board of Supervisors, County of Maui.
22. Camp No. 1 of Hawaiian Commercial & Sugar Co., near Spreckelsville, 5 miles east of Kahului; 50 feet above sea level; records furnished by Hawaiian Commercial & Sugar Co.
23. Camp No. 7 of Hawaiian Commercial & Sugar Co., near Kihei, about 5 miles south of Puunene; 50 feet above sea level; records furnished by Hawaiian Commercial & Sugar Co.
24. Puunene, at Hawaiian Commercial & Sugar Co.'s office; 50 feet above sea level; records furnished by Hawaiian Commercial & Sugar Co.

HAWAII.

1. Near flume at camp No. 8 of Waiakea plantation, near Waiakea; 1,500 feet above sea level; records furnished by Waiakea Plantation Co.
2. Camp No. 6, at plantation camp back of Waiakea; 800 feet above sea level; records furnished by Waiakea plantation.
3. United States Engineer's office at Hilo breakwater, Hilo; 15 feet above sea level; records furnished by United States Engineers' office.
4. Piihonua, at office and store of Hawaii Mill Co., near Hilo; 915 feet above sea level; records furnished by Hawaii Mill Co.
5. Hilo, in rear of J. T. Lewis's residence, Waianuenue Street; 60 feet above sea level.
6. Station No. 1, about 50 feet in rear of Alex. Valentine's house at Wainaku camp of Hilo Sugar Co.; 200 feet above sea level; records June 30 to November 30 furnished by Alex. Valentine, of Hilo Sugar Co.
7. Station No. 2, at Antone Mogordo's blacksmith shop near Kaiwiki road, and about 1 mile above the Wainaku camp of the Hilo Sugar Co.; 1,000 feet above sea level.
8. Station No. 3, near Kaiwiki, on trail from mauka end of Kaiwiki road to 2,700-foot camp, and about 600 feet above end of road; at lower edge of timber; 1,500 feet above sea level.
9. Station No. 4, on trail from mauka end of Kaiwiki road to 2,700-foot camp, in timber belt; 2,000 feet above sea level.
10. Station No. 5, about 3½ miles above Kaiwiki,[1] near Hilo; 2,650 feet above sea level.
11. Station No. 6, at camp, on east slope of Mauna Kea, in heavy timber belt; 3,000 feet above sea level.
12. Station No. 7, on east slope of Mauna Kea, in heavy timber belt; 3,500 feet above sea level.

[1] Gage originally located at elevation of 2,500 feet by H. R. Schulz; later moved to elevation of 2,650 feet; thought to be 2,500 feet by C. H. Pierce, July 1, 1911.

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13. Station No. 8, on east slope of Mauna Kea, in heavy timber belt; 4,000 feet above sea level.
14. Station No. 9, on east slope of Mauna Kea, in heavy timber belt; 4,500 feet above sea level.
15. Station No. 10, on east slope of Mauna Kea, in heavy timber belt; 5,000 feet above sea level.
16. Umikoa, on property of Kukaiau Ranch Co. (Ltd.), near ranch house; 3,400 feet above sea level; records furnished by Kukaiau Ranch Co. (Ltd.).
17. Puukihe, on top of Kihe hill on the side of Mauna Kea, about 10 miles south of Kukaiau; 7,822 feet above sea level; records furnished by Kukaiau Ranch Co. (Ltd.).
18. Reservoir No. 13, on land of Honokaa Sugar Co., near Honokaa; 1,480 feet above sea level; records furnished by the civil engineers' office of Honokaa Sugar Co. and Pacific Sugar Mill.
19. Near Honokaa, at office of civil engineers for Pacific Sugar Mill and Honokaa Sugar Co.; 1,120 feet above sea level; records furnished by civil engineers.
20. Ahualoa homesteads, at ditch tender's house, near the Parker ranch, Honokaa; 2,551 feet above sea level; records furnished by civil engineers' office of Honokaa Sugar Co. and Pacific Sugar Mill.
21. Waima, in Waipio Valley along the line of lower Hamakua ditch, near Kukuihaele; 980 feet above sea level; records furnished by Hawaiian Irrigation Co.
22. Lower Koiawe, near the line of the lower Hamakua ditch in Waipio Valley near Kukuihaele; 1,000 feet above sea level; records furnished by Hawaiian Irrigation Co.
23. Upper Koiawe, along the line of the upper Hamakua ditch, Waipio Valley, near Kukuihaele; 3,350 feet above sea level; records furnished by Hawaiian Irrigation Co.
24. Alakahi-Waipio, in Waipio Valley, Kohala Mountains, along the line of the lower Hamakua ditch, near Kukuihaele; 1,030 feet above sea level; records furnished by Hawaiian Sugar Co.
25. Alakahi-Waipio, in Waipio Valley, Kohala Mountains, near the line of the upper Hamakua ditch; 3,870 feet above sea level; records furnished by Hawaiian Irrigation Co.
26. Lower Kawainui, in Waipio Valley, near the line of the lower Hamakua ditch, near Kukuihaele; 1,040 feet above sea level; records furnished by Hawaiian Irrigation Co.
27. Upper Kawainui, in the Kohala Mountains, near the line of the upper Hamakua ditch, near Kukuihaele; 4,080 feet above sea level; records furnished by Hawaiian Irrigation Co.
28. Honokane mauka; in the Kohala Mountains, near the intake of the Kehena ditch, near Kohala; 3,800 feet above sea level; records furnished by Kohala Ditch Co.
29. Kaauhuhu, on property of W. S. May, about 3 miles northwest of Hawi; 1,400 feet above sea level; records furnished by W. S. May.

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Precipitation and estimated evaporation (in inches) at rainfall stations maintained during 1913.

Kauai.

Station.	Records available.	Gage.	Readings.	Precipitation.													Estimated evaporation.
				Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	For 1913.[a]	
1. Kokee	June 6, 1910, to Dec. 31, 1913	8-inch 2:1	Monthly													48.30	6
2. Puu Lua	June 5, 1910, to Dec. 31, 1913	do	do													45.66	6
3. Lehuamakanoi	June 18, 1910, to Dec. 31, 1913	13-inch, 5:1	Bimonthly													134.8	6
4. Paukahana	June 4, 1910, to Dec. 31, 1913	8-inch, 2:1	Monthly													77.0	6
5. Waiakoali	do	do	do													76.8	6
6. Kilohana	June 18, 1910, to Dec. 31, 1913	13-inch, 5:1	Irregular													216.0	6
7. Mohihi	June 21, 1910, to Dec. 31, 1913	8-inch, 2:1	do													83.8	6
8. Mohihi-Koaie divide	June 24, 1910, to Dec. 31, 1913	do	Bimonthly													88.0	6
9. Waialae	July 31, 1910, to Dec. 31, 1913	do	Monthly													89.2	6
10. Hukipo	January, 1911, to Dec. 31, 1913	Owned by Kekaha Sugar Co.	Probably monthly.	1.12	1.21	0	0	3.19	2.17	1.48	0.45	0.65	3.84	2.80	0	18.91	2
11. Pali trail	June 1, 1911, to Dec. 31, 1913	do	do	1.24	2.10	0	0	4.01	2.57	.78	0	1.59	5.14	.50	0	19.93	2
12. Camp No. 7	Jan. 1, 1904, to Dec. 31, 1913	Owned by Hawaiian Sugar Co.	Probably daily.	.80	1.68	0	0	5.36	2.70	.14	.41	1.12	5.90	2.23	0	22.34	2
13. Waimea (see table, p. 184).	Jan. 1 to Dec. 31, 1913	Small weather bureau gauge, 1:10.	Daily	1.20	1.96	0	.21	4.51	2.95	1.23	.37	.78	6.10	2.18	.09	23.58	2
14. Kaholuamanu	Mar. 11 to Dec. 31, 1913	8-inch, 2:1	Monthly													[b] 52.88	4
15. Kahana	Aug. 1, 1910, to Dec. 31, 1913	do	Irregular													84.70	6
16. Keanakua	Sept. 6, 1910, to Dec. 31, 1913	do	do													101.40	6
17. Olokele mauka	Apr. 1, 1911, to Dec. 31, 1913	Owned by Hawaiian Sugar Co.	Probably monthly.	15.25	5.10	5.06	14.28	11.24	10.53	7.98	10.25	4.76	13.44	27.35	.74	131.98	6
18. Waialeale	Sept. 9, 1910, to Dec. 31, 1913	13-inch, 5:1	Irregular													453.0	6
19. Camp No. 2	January, 1905, to Dec. 31, 1913	Owned by Hawaiian Sugar Co.	Probably daily.	1.07	2.06	0	.15	5.75	6.17	.42	1.17	.63	5.37	4.23	0	29.02	2
20. Hanapepe Valley (see table, p. 184).	Jan. 1, 1905, to Dec. 31, 1913	do	Daily	9.08	3.54	5.05	11.26	9.42	10.92	7.73	10.44	3.66	14.18	25.61	.69	113.58	2
21. Hiloa - Manawaiopuna divide.	Aug. 24, 1910, to Dec. 31, 1913	8-inch, 2:1	Monthly	18.90	6.40	9.80	25.20	15.30	17.80	16.20	15.40	6.60	18.40	43.40	8.40	207.80	6
22. Aakukui	June, 1909, to Dec. 31, 1913	Owned by Grove Farm.	Probably daily.	3.98	6.43	5.08	4.28	5.97	8.21	2.30	2.27	2.42	6.15	11.80	1.55	66.44	6
23. Waiahi	Aug. 8, 1910, to Dec. 31, 1913	8-inch, 2:1	Monthly	6.16	4.00	6.14	8.10	10.16	10.16	2.06	2.10	([c])	[c] 2.16	22.06	2.04	81.14	6
24. Hanahanapuni	do	do	do	4.08	6.18	6.04	8.00	8.12	12.00	2.18	6.02	4.16	8.00	20.40	6.04	97.22	6
25. North Wailua	July 20, 1912, to Dec. 14, 1913	13-inch, 5:1	Quarterly													265.2	6
26. Pohakupili	July 25, 1910, to Dec. 31, 1913	do	do													124.7	6
27. Puu Ku	do	do	Irregular													210.2	6
28. Kaneha	Jan. 1 to Dec. 31, 1913	Owned by Makee Sugar Co.	Probably daily.	5.85	5.80	10.85	5.15	10.35	8.90	4.75	3.35	3.35	6.40	14.40	7.70	88.85	2

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29. Summit Camp, Hanalei (see table, p. 184)	September, 1910, to Dec. 31, 1913		Daily	17.92	8.93	15.49	17.04	21.47	14.47	12.27	11.91	8.95	13.80	31.16	7.81	183.22	2
30. Kapaka (see table, p. 184).	do		do	9.82	7.84	11.57	7.43	10.46	8.53	9.03	7.67	5.08	6.93	19.10	9.49	114.95	2
31. Sanborn's residence, Hanalei.	March, 1910, to Dec. 31, 1913		do	4.46	6.39	5.33	5.71	6.28	4.69	5.13	5.00	2.54	6.18	12.12	6.63	72.46	2
32. Power house near Wainiha (see table, p. 184).	February, 1907, to Dec. 31, 1913		do	8.39	10.50	12.41	10.51	5.22	5.44	6.92	7.21	3.15	5.22	17.34	8.65	102.96	2
33. Intake of Wainiha Canal (see table, p. 184).	Feb. 1, 1907, to Dec. 31, 1913		do	6.91	6.01	27.99	13.68	7.25	10.22	11.83	9.54	5.20	9.18	28.03	8.81	146.65	2
Oahu.																	
1. Nuuanu, Pali	Sept. 23, 1910, to Dec. 31, 1913	8-inch, 2:1	Monthly	10.30	7.92	7.40	5.70	9.60	12.90	3.00	9.20	5.20	3.10	15.20	14.60	110.12	6
2. Mount Konahuanui	Oct. 27, 1910, to Dec. 31, 1913	do	do	7.0	8.6	8.4	5.4	9.4	12.6	3.6	8.4	4.2	5.4	10.6	11.2	100.8	6
3. Mount Olympus	Jan. 1 to Dec. 31, 1913	do	do	4.6	6.0	7.2	2.4	7.4	8.0	2.4	5.0	3.0	4.8	9.0	4.4	70.2	6
4. Waiomao	Oct. 1, 1910, to July 31, 1913	1:10	Weekly	2.88	4.37	5.56	7.71	5.35	4.37	2.73						[d] 33.97	1
5. Kaau crater	Jan. 1 to Dec. 31, 1913	8-inch, 2:1	Monthly	5.0	8.1	8.0	9.0	5.0	8.0	3.4	6.8	3.0	5.2	18.0	16.8	102.3	6
6. Waiawa-Waiahole ridge.	Dec. 5, 1910, to Dec. 31, 1913	do	do	16.70	8.64	9.00	9.00	12.50	13.60	5.80	10.50	7.50	12.25	23.50	16.10	151.09	6
7. Makaha near Waianae (see table, p. 184).	Aug. 1, 1912, to Dec. 31, 1913	1:10	Daily	5.95	3.43	6.26	3.94	13.62	6.59	1.39	4.02	4.22	8.80	7.78	12.41	80.41	2
8. Waialua Agricultural Co.'s intake.	May 30 to Dec. 31, 1913	8-inch, 2:1	Monthly						[e] 18.6	[f] 3.6	11.9	8.6	12.8	39.6	14.0	113.1	4
9. Hawaiian Preserving Co. (see table, p. 184).	Mar. 1 to Dec. 31, 1913	1:10	Daily			2.32	4.00	5.32	0.	2.36	3.57	3.51	4.76	5.78	.82	34.44	2

[a] Includes estimated evaporation.
[b] Obtained from irregular monthly readings as follows:

	Inches.
Mar. 11 to Apr. 11	2.00
May 8	3.00
June 9	9.00
July 19	3.20
Aug. 7	.80
Sept. 11	4.40
Oct. 12	5.00
Nov.	4.60
Dec. 2	14.20
Dec. 31	2.68
	48.88
Estimated evaporation	4.00
	52.88

[c] Hole in container; no water. New gage installed Oct. 15.
[d] Precipitation during part of year 1913 for which records are available.
[e] Includes rainfall to July 11.
[f] Record begins July 12.

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Precipitation and estimated evaporation (in inches) at rainfall stations maintained during 1913—Continued.

Maui.

Station.	Records available.	Gage.	Readings.	Precipitation.													Estimated evaporation.
				Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	For 1913.[a]	
1. Penhallow's yard, Wailuku.	November, 1896, to Dec. 31, 1913	1:10	Daily	0.63	7.23	1.17	2.40	5.66	0.59	0.22	2.01	0.58	1.25	3.82	4.20	31.76	2
2. Wailuku	May, 1887, to Dec. 31, 1913	1:10	do	.37	5.51	1.17	2.38	6.32	.49	.11	1.42	.48	1.06	3.31	3.00	27.62	2
3. Iao Valley, near Wailuku.	Apr. 12, 1911, to Dec. 31, 1913	8-inch, 2:1	Irregular													[b] 79.0	6
4. Iao Valley tableland	do	do	do													[b] 114.4	6
5. Cave in Iao Valley	Nov. 5, 1910, to Dec. 31, 1913	do	do													[b] 131.9	6
6. Waiehu	January, 1910, to Dec. 31, 1913	1:10	Daily	.45	5.57	1.33	2.39	6.52	1.41	.48	1.40	.91	1.00	2.97	4.93	31.36	2
7. Waihee	Jan. 1 to Dec. 31, 1913	1:10	do	.62	2.54	1.70	2.48	5.21	1.30	.27	1.43	.61	.60	3.03	4.37	25.16	1
8. Waihee Gulch	Nov. 4, 1910, to Dec. 31, 1913	10:1	Irregular													238.2	6
9. Mount Eke	Mar. 10 to Dec. 31, 1913	8-inch, 2:1	Monthly													[b] 218.7	6
10. Honokahau Gulch	February, 1907, to Dec. 31, 1913	1:10	Daily	3.19	12.88	6.90	17.72	9.83	9.48	5.06	7.77	3.00	5.57	26.03	15.18	125.61	3
11. Ridge at Honokahau.	Mar. 10 to Dec. 26, 1913	8-inch, 2:1	Monthly													[b] 93.7	6
12. Honokahua Gulch	Jan. 1 to Dec. 31, 1913	1:10	Daily	1.72	4.57	4.07	9.67	7.09	3.82	2.16	3.57	1.53	2.10	10.59	4.50	57.39	2
13. Honokawai Gulch	Oct. 17, 1911, to Dec. 31, 1913	8-inch, 2:1	Monthly	7.38	8.08	6.78	17.92	8.37	7.18	4.95	6.68	3.10	6.00	20.98	9.36	112.78	6
14. Puu Kukui, near Lahaina.	Oct. 13, 1911, to Dec. 31, 1913	13-inch, 5:1	do	14.0	6.0	12.0	16.0	9.5	7.03	9.0	6.5	3.2	6.0	21.5	7.5	124.23	6
15. Puu Kukui, near Kaanapali.	do	do	do	38.0	22.0	31.0	50.0	16.0	37.0	18.0	20.0	7.0	13.5	55.0	26.5	337.0	3
16. Olowalu	Jan. 1, 1907, to Dec. 31, 1913	1:10	Daily	.90	5.24	.05	0	11.75	.40	0	1.17	0	.72	.50	.27	22.00	1
17. Olowalu Gulch	Nov. 1, 1911, to Dec. 31, 1913	8-inch, 2:1	Monthly													120.75	6
18. Waikapu Gulch	Nov. 3, 1910, to Dec. 31, 1913	do	Irregular													111.9	6
19. Olinda	Sept. 26, 1910, to Nov. 21, 1913	1:10	Daily	.86	2.46	1.55	3.47	1.97	1.78	.52	1.43	2.32	4.57	12.29		[c] 35.22	2
20. Waikamoi Gulch	Oct. 12, 1910, to Dec. 31, 1913	1:10	do	5.10	13.03	8.10	53.35	9.68	13.70	13.33	14.29	19.17	14.35	45.54	16.09	227.73	2
21. Puohakamoa	May 1, 1911, to Dec. 31, 1913	8-inch, 2:1	do	10.40	10.60	8.44	47.80	9.57	14.19	7.78	13.11	18.18	14.61	41.69	16.14	214.5	2
22. Camp No. 1	Jan. 1 to Dec. 31, 1913	1:10	do	.10	2.16	.88	2.17	5.46	.17	0	1.50	.60	.63	3.52	3.72	22.91	2
23. Camp No. 7	Jan. 1, 1910, to Dec. 31, 1911; Jan. 1 to Dec. 31, 1913.	1:10	do	0	2.36	.06	0	5.19	.07	0	.25	0	1.06	.31	1.01	11.31	1
24. Puunene	Jan. 1 to Dec. 31, 1913	1:10	do	.13	2.15	.16	.92	5.60	.22	0	1.26	.50	.47	2.27	2.81	17.49	1

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Hawaii.

1. Camp No. 8, Waiakea.	June 1 to Dec. 31, 1913		Monthly						17.00	9.75	10.75	5.75	6.75	44.50	11.75	[b]109.25	3
2. Camp No. 6, Waiakea.	July 1 to Dec. 31, 1913		do							11.03	12.60	6.12	6.60	39.01	9.45	[b] 90.8	6
3. Hilo breakwater	July 20, 1911, to Dec. 31, 1913	8-inch, 2:1	do	28.70	4.60	40.30	10.70	6.60	9.60	5.80	6.50	6.00	5.60	30.00	8.40	127.8	5
4. Piihonua (see table p. 184).	January to Dec. 31, 1912; Jan. 1 to Dec. 31, 1913.	1:10	Daily			11.61	18.08	10.77	15.19	12.50	12.95	6.16	6.54	43.14	9.16	[b]148.1	2
5. Hilo	Oct. 1, 1912, to July 31, 1913	8-inch, 2:1	Monthly	32.70	6.20	9.00	12.20	5.20	11.40	7.00						[b] 86.7	3
6. Station No. 1	July 21, 1911, to Nov. 30, 1913	do	do	32.0	6.2	9.6	12.8	6.4	8.4	5.8	8.0	4.8	4.4	31.8		[b]135.2	5
7. Station No. 2	June 19, 1911, to July 31, 1913	do	do	19.8	5.8	10.8	16.8	8.4	18.8	10.2						[b] 94.1	3.5
8. Station No. 3	May 23, 1911, to July 31, 1913	do	do	32.0	5.6	14.0	19.8	5.6	20.0	10.6						[b]111.1	3.5
9. Station No. 4	May 24, 1911, to July 31, 1913	do	do	36.0	6.6	17.0	25.2	9.2	23.4	11.8						[b]132.7	3.5
10. Station No. 5	June 30, 1911, to July 31, 1913	do	do	35.6	6.2	16.2	27.2	9.6	21.2	14.0						[b]133.5	3.5
11. Station No. 6	Nov. 4, 1911, to June 30, 1913	13-inch, 5:1	Bimonthly	35.0		35.5		30.0								[b]103.5	3.0
12. Station No. 7	do	do	do	30.0		26.5		23.0								[b] 82.5	3
13. Station No. 8	Nov. 3, 1911, to June 30, 1913	do	do	26.5		23.0										[b] 51.5	2
14. Station No. 9	do	do	do	27.5		23.5		21.0								[b] 75.0	3
15. Station No. 10	Dec. 31, 1911, to June 30, 1913	do	do	30.5		25.5		26.0								[b] 85.0	3
16. Kukaiau ranch (see table, p. 185).	Jan. 1, 1911, to Dec. 31, 1913	Owned by Kukaiau Ranch Co.	Daily	3.08	3.29	1.64	3.45	5.46	2.66	0.	2.35	1.36	.30	22.03	17.20	64.8	2
17. Puukihe (see table, p. 185).	January, 1912,[c] to Dec. 31, 1913	do	Monthly													43.4	6
18. Reservoir No. 13 (see table, p. 184).	Jan. 1 to Dec. 31, 1913		Daily	3.48	9.31	3.15	3.19	3.98	2.40	1.82	4.46	5.05	.53	16.83	17.42	73.62	2
19. Near Honokaa (see table p. 184).	June, 1910, to Dec. 31, 1913		do	2.96	6.54	2.80	7.95	4.62	2.32	1.77	4.36	2.86	.50	17.63	21.67	77.98	2
20. Ahualoa homesteads (see table, p. 184).	Jan. 1 to Dec. 31, 1913		do	2.03	3.72	1.98	5.68	6.20	3.02	2.42	4.28	2.81	.59	25.78	16.95	77.46	2
21. Waima (see table, p. 185).	Apr. 1 to Dec. 31, 1913		do				5.92	5.09	6.33	3.62	4.06	2.96	.67	19.82	11.23	[b] 61.7	2
22. Lower Koiawe (see table, p. 185).	September, 1910, to Dec. 31, 1913		do	4.45	4.44	4.67	6.77	6.58	7.41	4.37	4.86	3.96	1.49	18.13	14.04	83.17	2
23. Upper Koiawe (see table, p. 185).	January, 1912, to Dec. 31, 1913		do				7.60	10.10	13.50	5.08	9.00	3.38	2.63	22.76	8.93	85.0	2
24. Alakahi - Waipio, lower (see table, p. 185).	September, 1910, to Dec. 31, 1913		do	5.39	7.61	9.49	12.35	12.98	15.45	8.45	9.58	9.62	2.97	33.83	25.29	159.0	6
25. Alakahi-Waipio, upper (see table, p. 185).	Jan. 1 to Dec. 31, 1913		do	4.87	9.15	9.55	19.72	10.42	16.97	13.30	11.72	7.28	4.27	41.30	14.85	169.4	6
26. Lower Kawainui (see table, p. 185).	September, 1910, to Dec. 31, 1913		do	3.94	6.48	6.93	8.80	8.64	12.01	6.32	9.20	5.68	2.21	34.44	27.22	132.9	2
27. Upper Kawainui (see table, p. 185).	July, 1907, to Dec. 31, 1913		do	10.41	11.39	15.73	28.82	14.64	24.54	20.92	18.46	13.75	6.17	56.62	18.86	246.3	6
28. Honokane mauka	Jan. 1 to Oct. 31, 1913		do	5.35	8.16	7.25	13.57	10.46	13.04	10.91	9.21	6.29	3.40			[b] 92.64	5
29. Kaauhuhu (see table, p. 185).	Mar. 18, 1912, to Dec. 31, 1913		do	2.60	4.71	2.29	6.39	3.72	6.56	4.00	3.34	2.51	2.01	11.53	10.10	61.76	2

[a] Includes estimated evaporation.
[b] Precipitation for part of year 1913 for which records are available.
[c] Precipitation Jan. 1 to Nov. 21, 1913, when gage was removed.
[d] Gage found leaking; new gage installed Apr. 1.
[e] Precipitation for year 1912—38.7 inches; includes 6 inches for estimated evaporation.

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Maximum precipitation, in inches, at rainfall stations maintained during 1913.

Month.	Kauai.							
	13. Waimea.		20. Hanapepe Valley near Koula.		29. Summit camp, Hanalei.		30. Kapaka.	
	Rainfall.	Maximum in 24 hours.	Rainfall.	Maximum in 24 hours.	Rainfall.	Maximum in 24 hours.	Rainfall.	Maximum in 24 hours.
January	1.20	0.70	9.08	1.74	17.92	2.21	9.82	1.42
February	1.96	.73	3.54	.65	8.93	2.65	7.84	2.00
March	0	0	5.05	.66	15.49	2.46	11.57	1.83
April	.21	.19	11.26	2.19	17.04	2.24	7.43	1.36
May	4.51	2.32	9.42	2.98	21.47	7.00	10.46	2.30
June	2.95	2.75	10.92	4.50	14.47	4.62	8.53	1.78
July	1.23	.81	7.73	1.28	12.27	1.62	9.03	1.22
August	.37	.11	10.44	1.96	11.91	1.09	7.67	.86
September	.78	.15	3.66	.72	8.95	1.69	5.08	.68
October	6.10	3.81	14.18	2.63	13.80	1.39	6.93	1.58
November	2.18	1.73	25.61	4.97	31.16	3.82	19.10	2.87
December	.09	.06	.69	.29	7.81	2.55	9.49	3.62
For 1913	21.58	3.81	111.58	4.97	181.22	7.00	112.95	3.62
Estimated evaporation	2.00	.....	2.00	.....	2.00	.....	2.00	.....
	23.58	.....	113.58	.....	183.22	.....	114.95	.....

Month.	Kauai.				Oahu.			
	32. Power house near Wainiha.		33. Intake of Wainiha canal.		7. Makaha near Waianae.		9. Hawaiian Preserving Co.	
January	8.39	2.76	6.91	1.69	5.95	1.64	.....	.....
February	10.50	2.85	6.01	1.05	3.43	1.30	.....	.....
March	12.41	2.75	27.99	9.40	6.26	4.00	2.32	0.59
April	10.51	1.61	13.68	2.61	3.94	1.90	4.00	.51
May	5.22	1.43	7.25	1.55	13.62	6.40	5.32	1.76
June	5.44	.99	10.22	1.65	6.59	3.00	0	.....
July	6.92	1.97	11.83	2.50	1.39	.64	2.36	1.00
August	7.21	.81	9.54	1.15	4.02	2.60	3.57	.85
September	3.15	.81	5.20	1.47	4.22	2.60	3.51	.37
October	5.22	1.77	9.18	3.35	8.80	4.70	4.76	1.30
November	17.34	1.89	28.03	4.90	7.78	2.21	5.78	1.27
December	8.65	4.39	8.81	3.18	12.41	9.14	.82	.32
For 1913	100.96	4.39	144.65	9.40	78.41	9.14	32.44	1.76
Estimated evaporation	2.00	.....	2.00	.....	2.00	.....	2.00	.....
	102.96	.....	146.65	.....	80.41	.....	34.44	.....

Month.	Hawaii.							
	4. Piihonua.		18. Reservoir No. 13.		19. Near Honokaa.		20. Ahualoa homesteads.	
January	.....	.....	3.48	1.27	2.96	0.80	2.03	0.54
February	.....	.....	9.31	3.00	6.54	2.00	3.72	.72
March	11.61	1.96	3.15	1.16	2.80	.82	1.98	.72
April	18.08	1.95	3.19	1.16	7.95	1.73	5.68	1.47
May	10.77	3.20	3.98	1.12	4.62	1.80	6.20	1.76
June	15.19	6.00	2.40	1.25	2.32	1.68	3.02	.77
July	12.50	1.75	1.82	.45	1.77	.93	2.42	1.05
August	12.95	2.40	4.46	.85	4.36	1.08	4.28	.66
September	6.16	1.10	5.05	1.85	2.86	.70	2.81	.80
October	6.54	1.71	.53	.12	.50	.25	.59	.14
November	43.14	6.00	16.83	3.62	17.63	3.35	25.78	7.06
December	9.16	2.07	17.42	5.00	21.67	9.20	16.95	6.37
For 1913	146.1	6.00	71.62	5.00	75.98	9.20	75.46	7.06
Estimated evaporation	2.0	.....	2.00	.....	2.00	.....	2.00	.....
	148.1	.....	73.62	.....	77.98	.....	77.46	.....

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Maximum precipitation, in inches, at rainfall stations maintained during 1913—Contd.

Month.	Hawaii.							
	21. Waima.		22. Lower Kolawe.		23. Upper Kolawe.		24. Alakahi-Waipio, lower.	
January	.....	.....	4.45	1.14	.....	.....	5.39	1.57
February	.....	.....	4.44	1.22	.....	.....	7.61	1.58
March	.....	.....	4.67	.75	.....	.....	9.49	1.83
April	5.92	1.20	6.77	1.36	7.60	1.00	12.35	3.10
May	5.09	.95	6.58	.95	10.10	2.00	12.98	1.75
June	6.33	1.50	7.41	1.55	13.50	2.10	15.45	2.89
July	3.62	1.00	4.37	1.10	5.08	.60	8.45	1.75
August	4.06	1.30	4.86	.90	9.00	1.70	9.58	1.74
September	2.96	.88	3.96	.96	3.38	.57	9.62	3.52
October	.67	.25	1.49	.40	2.63	.65	2.97	.49
November	19.82	5.20	18.13	4.20	22.76	4.55	33.83	6.92
December	11.23	6.20	14.04	4.30	8.93	2.35	25.29	9.25
For 1913	59.70	6.20	81.17	4.30	82.98	4.55	153.0	9.25
Estimated evaporation	2.00	.....	2.00	.....	2.00	.....	6.0	.....
	61.7	.....	83.17	.....	85.0	.....	159.0	.....

Month.	Hawaii.							
	25. Alakahi-Waipio, upper.		26. Lower Kawainui.		27. Upper Kawainui.		29. Kaauhuhu.	
January	4.87	1.60	3.94	0.97	10.41	3.90	2.60	1.17
February	9.15	1.65	6.48	1.22	11.39	1.75	4.71	.66
March	9.55	2.10	6.93	1.40	15.73	3.63	2.29	.45
April	19.72	3.65	8.80	1.60	28.82	4.50	6.39	1.32
May	10.42	2.01	8.64	1.15	14.64	2.10	3.72	.89
June	16.97	2.60	12.01	2.20	24.54	3.05	6.56	1.26
July	13.30	2.21	6.32	1.20	20.92	3.63	4.00	1.90
August	11.72	2.30	9.20	1.80	18.46	3.32	3.34	.98
September	7.28	1.40	5.68	1.50	13.75	3.15	2.51	1.02
October	4.27	.60	2.21	.45	6.17	.73	2.01	.45
November	41.30	8.50	34.44	8.00	56.62	13.32	11.53	2.02
December	14.85	4.55	27.22	11.03	18.86	5.87	10.10	1.94
For 1913	163.4	8.50	131.87	11.03	240.3	13.32	59.76	2.02
Estimated evaporation	6.0	.....	2.00	.....	6.0	.....	2.00	.....
	169.4	.....	133.9	.....	246.3	.....	61.76	.....

Precipitation at rainfall stations maintained on Hawaii during 1911 and 1912.

Month.	16. Kukaiau ranch.		17. Puukihe.
	1911	1912	1912
	Inches.	*Inches.*	*Inches.*
January	12.49	0	.....
February	43.44	22.04	.....
March	3.30	10.61	.....
April	11.74	13.15	.....
May	9.49	1.93	.....
June	3.24	.11	.....
July	2.53	.67	.....
August	3.69	1.42	.....
September	3.77	1.47	.....
October	3.39	4.55	.....
November	4.72	6.53	.....
December	5.71	1.51	.....
Year	[a] 107.5	[a] 64.0	[b] 38.7

[a] Two inches should be added for estimated evaporation.
[b] Includes 6 inches estimated evaporation.

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FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

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WATER-SUPPLY PAPER 374

GROUND WATER
IN THE
HARTFORD, STAMFORD, SALISBURY, WILLIMANTIC AND SAYBROOK AREAS, CONNECTICUT

BY

HERBERT E. GREGORY AND ARTHUR J. ELLIS

Prepared in cooperation with the
Connecticut State Geological and Natural History Survey

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

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Water-Supply Paper 374

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GROUND WATER IN THE HARTFORD, STAMFORD, SALISBURY, WILLIMANTIC, AND SAYBROOK AREAS, CONNECTICUT.

By Herbert E. Gregory and Arthur J. Ellis.

INTRODUCTION.

THE PROBLEM.

The census of 1910 reported the population of Connecticut as 1,114,756. The area of the State is 5,004 square miles. The average density of population is therefore about 220 per square mile, but the distribution of population is markedly uneven. More than 53 per cent of the inhabitants are gathered into 19 cities, each containing over 10,000 souls. The cities are rapidly increasing in population, but parts of the State—about 24 per cent of the towns—are more sparsely settled to-day than in 1860. Broadly speaking, the people of Connecticut are engaged in two occupations—manufacturing and mixed agriculture. Manufacturing is increasing at a rapid rate; agriculture at a slower rate, but with a distinct tendency toward specialization. There is in addition a tendency to utilize the scenery of the State—a tendency resulting in the development of country estates and shore homes.

With an annual rainfall of 45 inches, Connecticut has in the aggregate large supplies of both surface and ground water, but the rainfall is sometimes deficient through periods of several weeks or months. Consequently farmers must endure periods of drought, manufacturers must provide against fluctuating water power, and the inhabitants of congested districts must arrange for adequate municipal supplies. With increase in population and diversification of interests conflicts between water-power users and domestic consumers, as well as between towns, for the right to make use of a particular stream or area have already arisen. Demands are also being made by prospective users of the waters for irrigation and drainage. The question of quality of water also takes on new meaning with the effort to improve the healthfulness of the State and to reclaim the waters now polluted by factory waste and sewage. The necessity for obtaining small but unfailing supplies of potable water for the farm and for the village home furnishes an additional problem, for the condition of many private supplies in Connecticut is deplorable.

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To meet the present situation and to provide for the future, State-wide regulations should be adopted. Obviously the first step in the solution of the Connecticut water problem is to make a comprehensive study of both surface and ground waters to obtain answers to the following questions: How much water is stored in the gravels and sands and bedrock of the State? How much does the amount fluctuate with the seasons? What is the quality of the water? How may it best be recovered in large amounts? In small amounts? What is the expense of procuring it? How much water may the streams of the State be relied upon to furnish? How much is the stream water polluted? How may the pollution be remedied? To what use should each stream be devoted? What is the equitable distribution of ground and surface waters among the conflicting claimants—industries and communities?

HISTORY OF THE INVESTIGATION.

The study of the water resources of Connecticut was begun in 1903 by the senior author of the present paper, under the auspices of the United States Geological Survey. A preliminary report was issued in 1904.[1] A discussion of the fundamental problems relating to the State as a whole, published in 1909,[2] meets in a broad way the requirements of the scientist and the engineer, but it is not designed to furnish a solution for local problems and is not sufficiently detailed to furnish data for use in a quantitative study of ultimate supply and its utilization. It was recognized that conditions in the State are so varied that each section of the State has its individual problem, and that in order to obtain data of direct practical value the conditions surrounding each town, and, where feasible, each farm and each village, should be investigated.

Realizing the importance of such studies to Connecticut, the State joined forces with the Federal Government in order to carry on this work. In 1911 a cooperative agreement was entered into by the United States Geological Survey and the Connecticut Geological and Natural History Survey for the purpose of obtaining information concerning the quantity and quality of waters available for municipal and private uses. The investigation was to be conducted through a period of two or more years, the cost to be shared equally by the parties to the agreement. Herbert E. Gregory, geologist, of the United States Geological Survey, was placed in charge of the investigation and Arthur J. Ellis, a junior geologist of the Federal Survey, was assigned to field work on ground waters. The present report

[1] Gregory, H. E. [notes on the wells, springs, and general water resources of], Connecticut: U. S. Geol. Survey Water-Supply Paper 102, pp. 127-168, 1904.

[2] Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, 1909.

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is the first of a series of papers which are so planned as to cover eventually all the towns of the State. As the funds available were meager it appeared wise to devote most of the time to a study of ground waters, leaving studies of stream flow to be taken up later. Certain stream measurements obtained by the United States Geological Survey and by corporations and individuals are available for use when the surface water problem is seriously attacked.

The field work on which the present report is based was done by the junior author during the seasons of 1911 and 1912. The work consisted in gathering information concerning municipal water supplies; measuring the dug wells used in rural districts and obtaining other data in regard to them; obtaining data concerning drilled wells, driven wells, and springs; collecting and analyzing samples of water from wells, springs, and brooks; studying the character and relations of bedrock and of surficial deposits with reference to their influence upon the ground-water supply. An effort was made to obtain records of all drilled wells in the areas under consideration, and as many dug wells were examined as was deemed necessary to determine the position of the water table throughout the areas.

The junior author is responsible also for the maps and for the larger part of the manuscript. The senior author's contribution includes formulation of plans, field and office conferences, and outlining and in part preparing the manuscript for publication.

ACKNOWLEDGMENTS.

The data relating to drilled wells were collected through the hearty cooperation of the well drillers in Connecticut. Other information that was of value in the preparation of this report was obtained from clerks of towns and from engineers of cities and of water companies, and services were rendered by Messrs. E. M. Hobby, Henry C. Cowles, Hadley G. Gray, G. L. Ladd, and Frank Palm in the collection of data in regard to changes of the water level in wells. The assistance thus received is acknowledged with thanks.

Free use has been made of the technical literature dealing with water supplies and credit is given for specific facts taken from these sources, but the report contains also material gathered from the reports of previous investigations, some of which can not be rightly attributed to any one author.

AREAS SELECTED FOR STUDY.

The areas with which this report is concerned represent the typical geologic conditions of Connecticut. (See fig. 1.) The Hartford area includes the towns of Hartford, West Hartford, Newington, Wethersfield, East Hartford, Manchester, Windsor, East Windsor,

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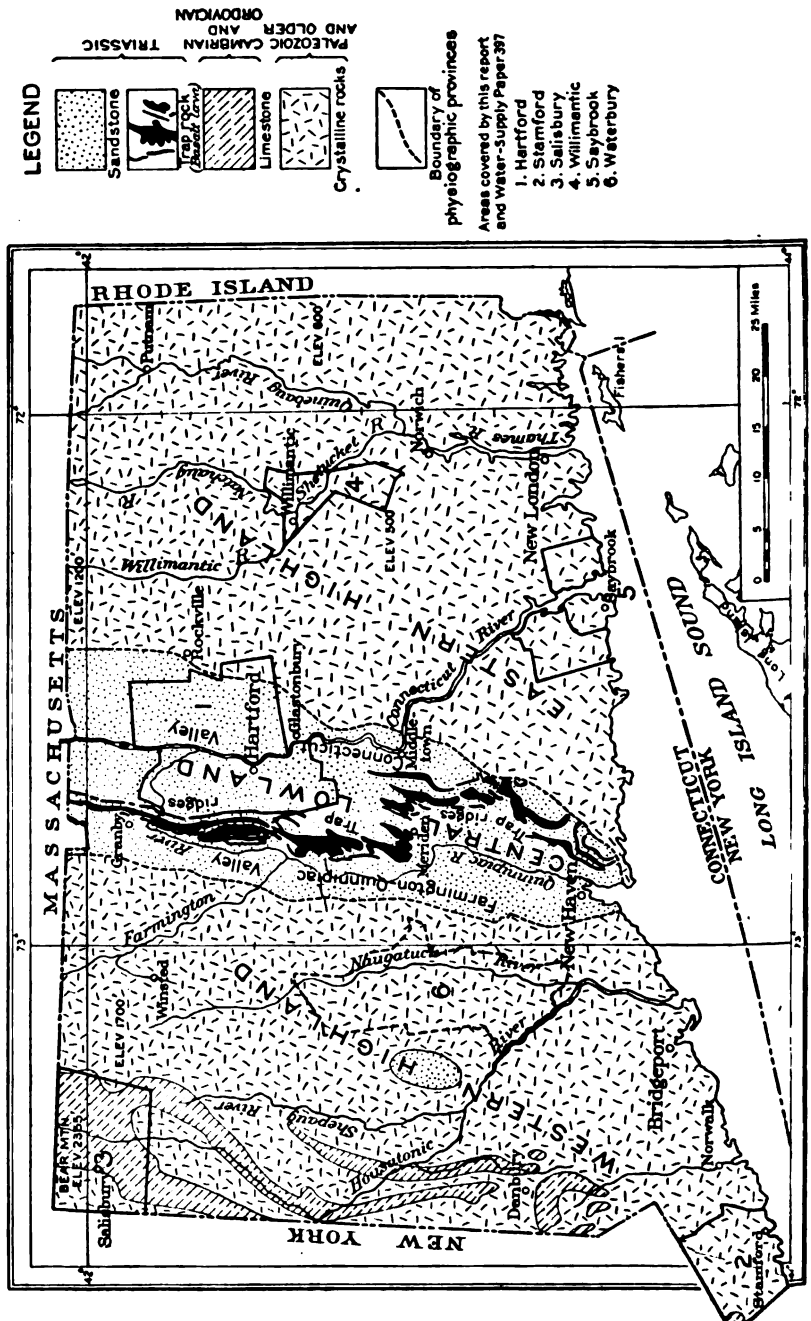

FIGURE 1.—Map of Connecticut showing physiographic provinces, geologic formations, and areas covered by this report.

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South Windsor, and Bloomfield. It lies in the Connecticut River valley and is underlain by Triassic sediments and lavas.

The Stamford area includes the towns of Stamford and Greenwich. It lies in the southwest corner of the State and is underlain by crystalline rocks.

The Salisbury area is in the northwest corner of the State and includes the towns of Salisbury, Canaan, and North Canaan. The lowlands in this area are underlain by limestone.

The towns of Windham and Franklin are designated in this report as the Willimantic area. They are situated in the eastern highlands and are underlain by metamorphic rocks of various types, on which a highly varied topography has been developed.

Saybrook, Essex, Westbrook, and Old Lyme, which comprise the Saybrook area, are at the mouth of Connecticut River, where the land is low and comparatively flat and where the presence of salt water is a feature of ground-water problems.

RELIABILITY OF DATA.

The principal well data are given in tables appended to the detailed reports on the several towns. The depth and diameter of the dug wells and the amount of water in them were determined by measurement. The information presented as to depth to rock and the consumption of water is in general based on data supplied by local residents. The elevations of the wells and springs were determined by means of a hand level, the base used for each determination being the assumed height of some point through which a mapped contour line would pass. The error may be as much as 10 or 15 feet in the most hilly sections but is doubtless usually less than 5 feet. The limitations of the accuracy of the mapping of underground surfaces must also be taken into account. The estimated yields of drilled wells are based on tests made by the drillers when the wells were completed; for some of the dug wells the yield was computed from observation of the length of time taken to pump the well dry, the known rate of pumping, and the dimensions of the well; for others the yield was estimated from the lowering of the water in a given length of time by pumping at a known rate. For wells from which nearly all the water available was being consumed the yield was computed from the amount used each day. Information concerning the yield of a few improved springs was obtained by actual measurements of the overflow; the yield of others was computed from measurements of the velocity and cross section of the streams issuing from them; for still others the figures given represent the yield as estimated by the owners.

The quantity of ground water available at any particular time depends on the character of the weather previous to that time. For

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the year 1911 the precipitation in Connecticut was somewhat less than the average; from January 1 until August 23 it was about 6 inches below normal. The fall of 1910 was dry, and many dug wells failed during the following winter. The drought was broken during the last part of the winter, and when the field work was begun in June the supply of water in dug wells was sufficient for domestic uses although not abundant. Practically no rain fell from the beginning of the summer until August 24, and by that time the water in dug wells was generally low and many wells had again failed. From August 24 to September 1, inclusive, it rained practically without ceasing. No wells were measured after it began to rain until September 5, so that four days were allowed for the wells to recover from flooding. However, the measurements made after September 5 showed a large average increase in the depth of water. From that time until the end of the year there were occasional rains and all wells yielded water.

During 1912 the rainfall was about normal up to the early part of July, so that in May, when field work was begun, wells were generally in satisfactory condition, and although the precipitation during the last part of the year was somewhat below normal, the number of wells that failed was considerably less than in 1911.

OCCURRENCE OF GROUND WATER.

ORIGIN.

The ground water of Connecticut is derived from the precipitation within the State and near its borders. Owing to the ruggedness of the surface of the bedrock and the thinness of the overlying drift, which together prevent extensive underground circulation, the ground water at any particular place comes from near-by sources.

The precipitation is evenly distributed over the State and is nearly uniform throughout the year, as shown in the following tables:

Average precipitation at 10 stations in Connecticut, 1893–1903.[a]

Month.	Inches.	Month.	Inches.
January	4.28	November	4.48
February	3.94	December	3.44
March	4.23		
April	3.53		46.98
May	4.03		
June	2.95	Average for season:	
July	4.42	Winter	11.66
August	4.30	Spring	11.79
September	3.34	Summer	11.67
October	4.40	Fall	11.82

[a] Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, p. 24, 1909.

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Geographic distribution of precipitation.[a]

Locality.	Average annual precipitation.	Years included.
	Inches.	
New Haven	45.89	[b] 1804–1908
Middletown	49.25	[c] 1859–1901
Hartford	44.30	[d] 1847–1908
Storrs	47.16	1897–1906
North Grosvenordale	45.00	[e] 1891–1908
Cream Hill	48.06	1897–1908

[a] Summaries of climatological data by sections: U. S. Weather Bureau Bull. W, vol. 2, sec. 105, p. 10, 1912.
[b] Except 1805, 1822 to 1826, 1828 to 1864, 1868 to 1872. Continuous record for 36 years, 1873 to 1908, inclusive, gives mean annual rainfall of 46.97 inches.
[c] Except 1860, 1863, 1883, 1884, 1892, 1898, 1899.
[d] Except 1853 to 1866, inclusive.
[e] Except 1898 and 1899.

The following table shows the monthly precipitation in Connecticut during 1911 and 1912 compared with the average monthly precipitation in the State:

Average monthly precipitation (in inches) in Connecticut, 1893–1903, 1911, and 1912.

Month.	Average of 10 stations, 1893–1903.	Average of 20 stations, 1911.	Average of 20 stations, 1912.
January	4.28	3.09	2.41
February	3.94	2.70	2.67
March	4.23	3.76	7.48
April	3.53	4.73	4.30
May	4.03	1.36	4.95
June	2.95	2.36	0.75
July	4.42	3.01	2.94
August	4.30	5.87	3.86
September	3.34	2.94	2.69
October	4.40	6.34	2.33
November	4.48	5.09	3.85
December	3.44	3.28	5.19
	47.34	44.53	43.42
January	4.28	3.09	2.41
January and February	8.22	5.79	5.08
January to March, inclusive	12.45	9.55	12.56
January to April, inclusive	15.98	14.28	16.86
January to May, inclusive	20.01	15.64	21.81
January to June, inclusive	22.96	18.00	22.56
January to July, inclusive	27.38	21.01	25.50
January to August, inclusive	31.68	26.88	29.36
January to September, inclusive	35.02	29.82	32.05
January to October, inclusive	39.42	36.16	34.38
January to November, inclusive	43.90	41.25	38.23
January to December, inclusive	47.34	44.53	43.42

WATER IN THE GLACIAL DRIFT.

CIRCULATION.

The chief water-bearing formations of Connecticut are the unconsolidated materials that cover the bedrock. These materials were derived from the great ice sheets which in the Pleistocene epoch extended over the State. They are of two general types: The unstratified drift, also called "till" (Pl. I, *A*), consists of heterogeneous mixtures of all the rock débris deposited directly by the ice;

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the stratified drift consists of glacial materials that were rehandled by water and is therefore assorted into layers of different degrees of coarseness (Pl. II, *A*).

The unconsolidated surface materials absorb rain water at a rate and to an extent depending chiefly on their porosity. The most porous beds are composed of gravel and sand, the least porous of compact clays. The unstratified drift, which covers most of the State, is a mixture of bowlders, gravel, sand, and clay and has a porosity depending upon the relative amounts of these materials. Much of the unstratified drift of Connecticut is of the "stony" or "bowldery" type, containing little or no clay and possessing a degree of porosity equal to that attained by coarse varieties of stratified drift. The less porous types of unstratified drift may be represented by the following average of the analyses of 16 samples collected from 12 drumlins in the Boston Basin.[1] These analyses were made after removing all stones 2 inches or more in diameter, or about 10 per cent of the original material.

Composition of unstratified drift in Boston Basin.

	Per cent.
Gravel	24.90
Sand	19.51
Rock flour	43.66
Clay (three-fourths rock flour)	11.67
	99.94

Other factors influencing the amount of water absorbed are the growth of vegetation, the topography, the occurrence and duration of frost in the ground, and the atmospheric conditions that determine evaporation and rates of precipitation.

The water absorbed by the soil descends and saturates the lower part of the glacial drift, which serves as a reservoir for the storage of this water. The efficiency of the drift in this respect depends largely on the rate of underground drainage, the three principal factors of which are porosity, the arrangement of layers having different porosities, and the topography of the bedrock on which the water-bearing bed rests. The most porous beds, as, for example, the dune sands of the Connecticut River valley (Pl. I, *B*), absorb water most rapidly, but they also allow the water to circulate most freely and are therefore most rapidly drained. Impervious materials, such as clays (Pl. II, *B*), occurring among porous deposits bear a relation to underground drainage similar to that between dams or other obstructions and surface drainage—they divert or impound the percolating waters and in many places produce springs and swamps. Except where the drift is thick, the topography of the bedrock below the

[1] Crosby, W. O., Composition of till or bowlder clay: Boston Soc. Nat. Hist. Proc., vol. 25, p. 124, 1890.

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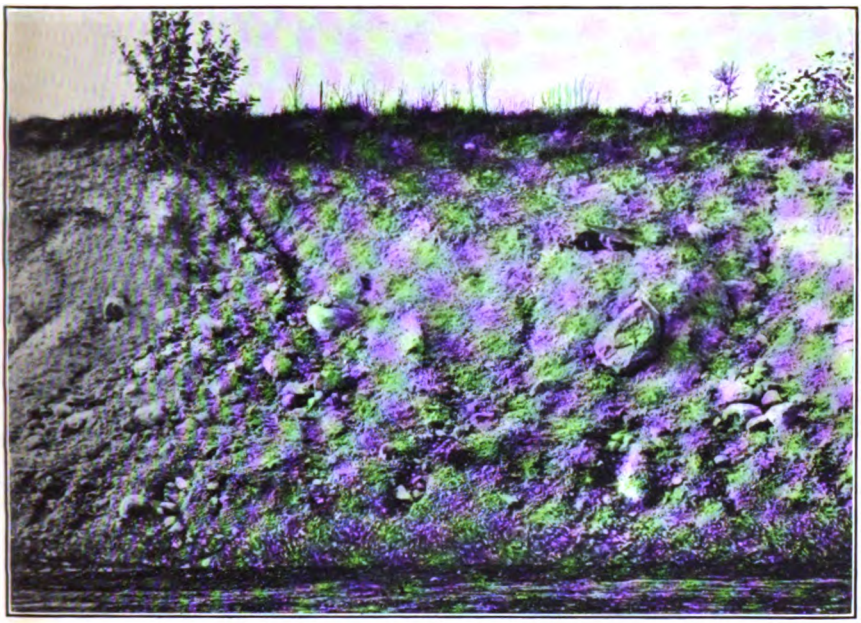
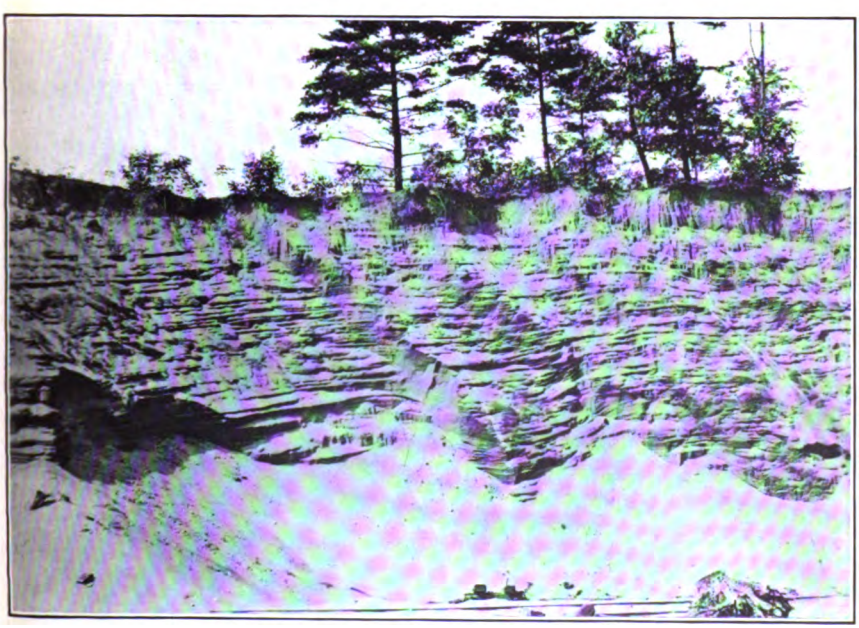


A. SECTION OF TILL, WINDHAM, CONN.



B. SECTION OF SAND DUNE, SOUTH WINDSOR, CONN.

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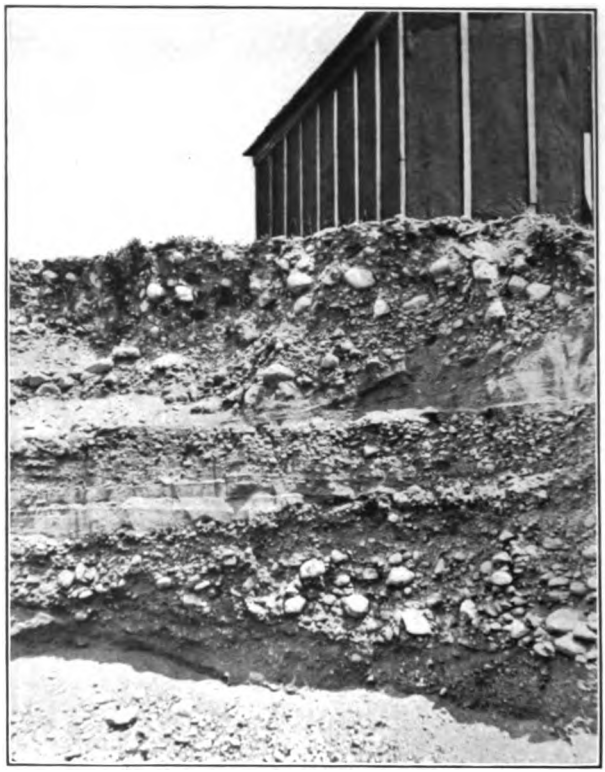

A. STRATIFIED DRIFT (GRAVEL), STAMFORD, CONN.

B. STRATIFIED DRIFT (CLAY), HARTFORD, CONN.

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water-bearing beds is related to underground drainage as the topography of the land is related to surface drainage. Over most of Connecticut the drift is thin and the topography of the bedrock surface closely conforms to the present topography of the land surface, except that it is more rugged and has greater relief. The bedrock crops out on many of the hilltops and steep slopes but lies far below the surface in the valleys (Pl. III). Because of the similarity between the forms of the rock surface and the surface of the ground, the direction of underground drainage corresponds very closely to the direction of surface drainage. The ground water, like the surface water, flows most rapidly on steep slopes, but because of the resistance offered by the soil particles it moves much more slowly than the surface water and is generally replenished by rainfall before the supply contributed by previous rain has been drained away. Most of the ground water finds its way to the surface through springs and seepage areas, by capillary rise and evaporation, and by transpiration of trees and other plants; the amount drawn from wells is comparatively small.

THE WATER TABLE.

The water table is the plane below which the ground is saturated with water. Its surface conforms somewhat to that of the land but is less rugged. It is generally nearest the land surface in the valleys; on the hilltops it may lie at depths of 30 to 40 feet. The surfaces of streams, ponds, and lakes are generally continuous with the water table and may be regarded as forming parts of it. In bogs, marshes, and other places where the ground is saturated to the surface, the water table and the surface of the ground coincide. Where the water table is not exposed, its position is indicated by the surface of the water in wells. The position of the water table depends also on the character of the drift. Except in very low places it is, in general, nearer the surface in areas where the drift consists of clay or compact till and farther below the surface in areas where the drift is gravel and sand, because clay and till are less porous than gravel and sand and do not drain so rapidly.

The accompanying maps, Plates IX to XIII (in pocket), represent the average position of the water table. Where dense rocks appear at or very near the surface there is no water table; the rock masses rise above the ground water like islands in a lake, and the position of the water table immediately surrounding them is indeterminate. Figure 2 illustrates the relative position of the water table in various kinds of drift and under different topographic conditions.

The water table is constantly changing its position with respect to the surface of the ground, rising rapidly after a heavy rain, then

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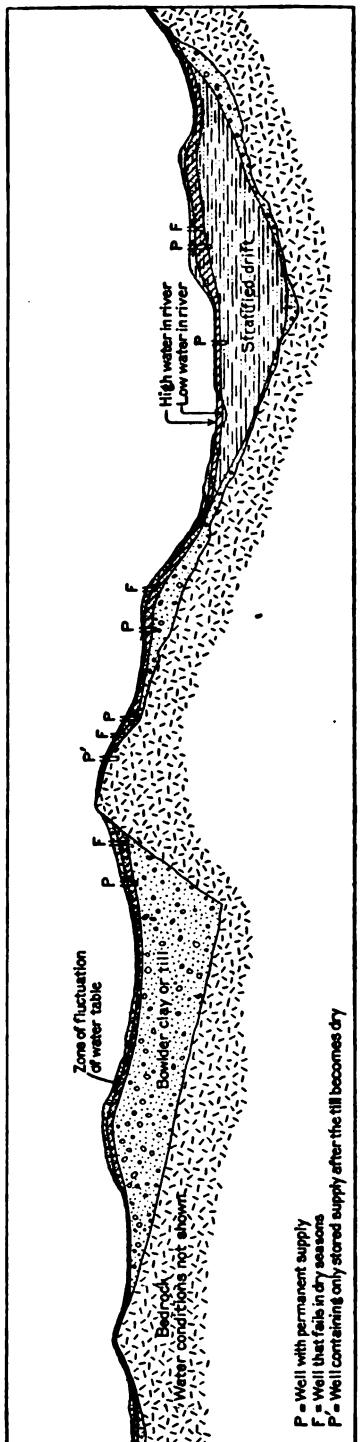

FIGURE 2.—Diagrammatic section illustrating position and fluctuation of the water table under various conditions.

gradually descending as the w is drained away. These cha may be observed by making s cessive measurements of the de to water in wells. The zo through which the water tab fluctuates is called in this repo the zone of fluctuation.

In elevated positions, where the drift is thin, the water table may descend during a period of drought until it touches the rock surface and the water is all drained away; but in the vicinity of perennial streams or permanent bodies of water the change may not exceed a few inches during the year. The zone of fluctuation is therefore narrowest in the valleys and widest on the hills, where it may include the entire distance from the highest water level to the bedrock surface. Figure 3 shows the fluctuation of the water table as determined from measurements of wells in four towns in Connecticut. Other data concerning these wells appear in the tables on pages 71, 108, 132, 141.

QUANTITY OF WATER.

A rough conception of the annual supply of ground water may be obtained by analyzing the relations between rainfall and stream flow. Measurements of the rainfall give the total amount of water which falls on a drainage basin, but only a part of this is contributed to the underground supply, the rest being in part returned to the atmosphere and in part discharged by surface streams. The total run-off from a drainage basin, as determined by stream measurements, includes both the surface drainage—that is, the

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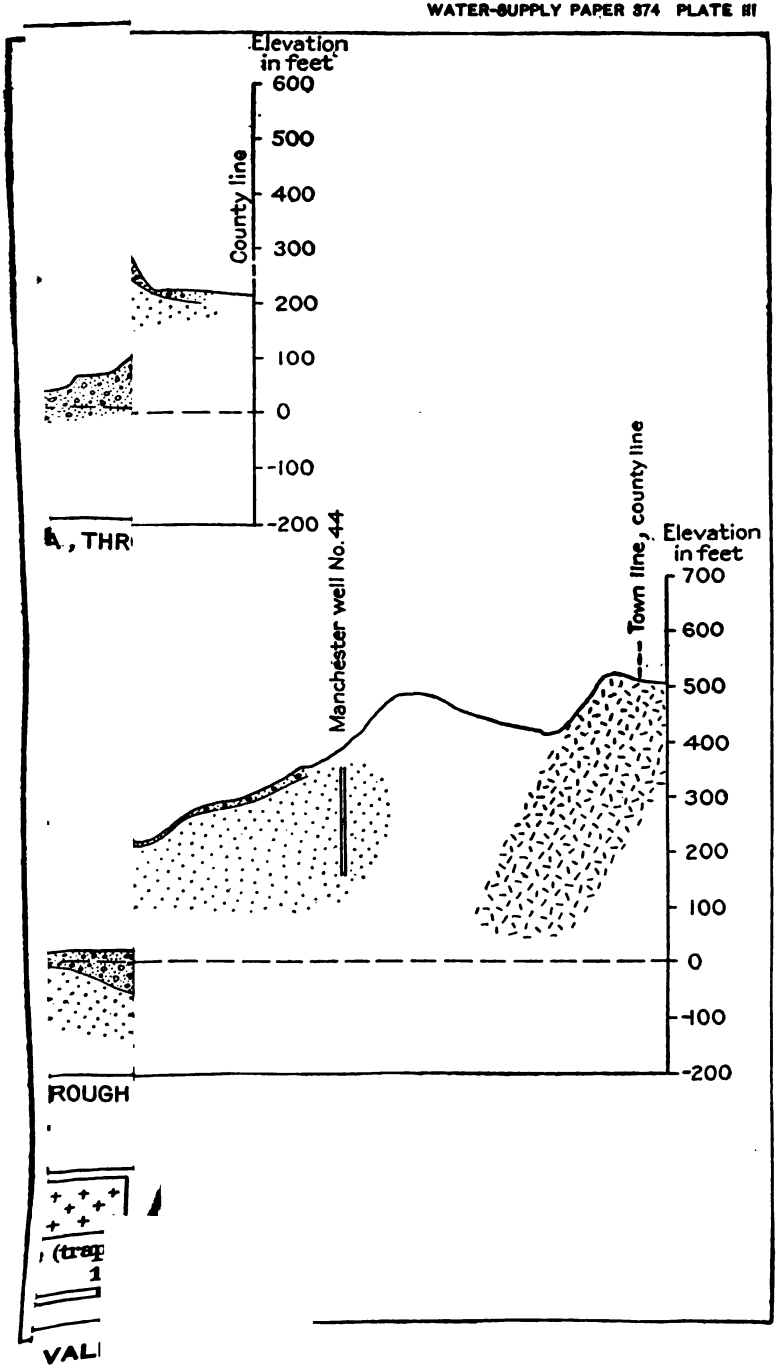

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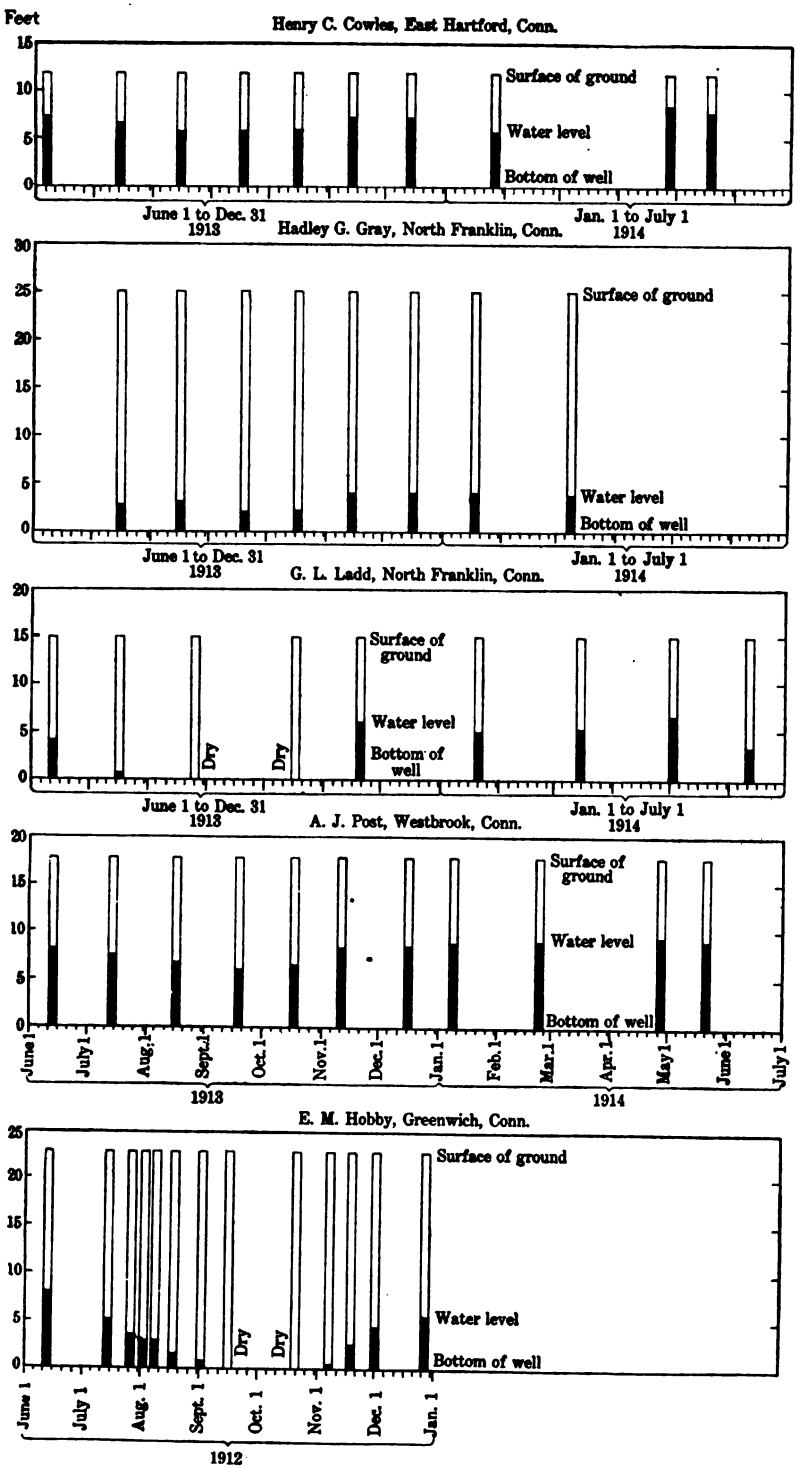

FIGURE 3.—Diagrams showing fluctuation of the water table in wells.

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water which has never formed part of the underground supply—and the underground drainage—the water that has passed into the surface streams from the water bed. The water which is returned to the atmosphere by evaporation and transpiration is in part surface water and in part ground water. A rough index of its quantity is obtained by subtracting the total annual run-off from the total annual precipitation. The annual rainfall in Housatonic River basin above Gaylordsville, Conn. (area, 1,020 square miles), is 47.86 inches and the annual run-off is 29.43 inches. The loss—18.43 inches—is attributed to evaporation, plant growth, and other causes. Similarly, in the basin of Connecticut River above Orford (area, 3,300 square miles) the annual precipitation is 36.76 inches and the annual run-off is 21.66 inches, the loss being 15.10 inches. These and other data compiled by J. C. Hoyt [1] indicate that in the northeastern United States between 30 and 40 per cent of the rainfall is returned to the atmosphere. It is not possible to determine from the data at hand what part of this water is derived from the underground supply. All perennial streams lie below the water table and are maintained during dry seasons by infiltration from the saturated part of the drift. During a rainy season and for some time thereafter the streams carry more or less water that has not been drawn from the ground water. During the succeeding dry season this surface water is discharged, and the streams finally reach a stage at which the run-off is derived almost entirely from the ground water. At low stages the discharge of ground water is not much less than the amount carried by the streams and it increases immediately after rains, owing to the contribution from intermittent springs and seepage areas and to a general acceleration of underground circulation by hydrostatic pressure. In addition to the ground water discharged by streams large quantities of water are stored in drift-filled rock basins below the valley floors, as, for example, in the valley of Connecticut River near Hartford, where saturated deposits consisting largely of sand extend nearly 100 feet below the river bed. The quantity of water in such basins depends on the size of the basins and the porosity of the valley fill; but if the water is withdrawn the basins must be replenished by water usually carried in the streams; therefore, strictly speaking, these supplies are not available in addition to the amounts carried by the streams.

WATER IN CRYSTALLINE ROCKS AND TRAPS.

CIRCULATION.

More than two-thirds of the area of Connecticut is underlain by crystalline rocks whose ages have not been precisely determined, and in the remaining third of the State various Triassic lava sheets,

[1] Hoyt, J. C., Comparison between rainfall and run-off in northeastern United States: Am. Soc. Civil Eng. Trans., vol. 59, p. 470, 1907.

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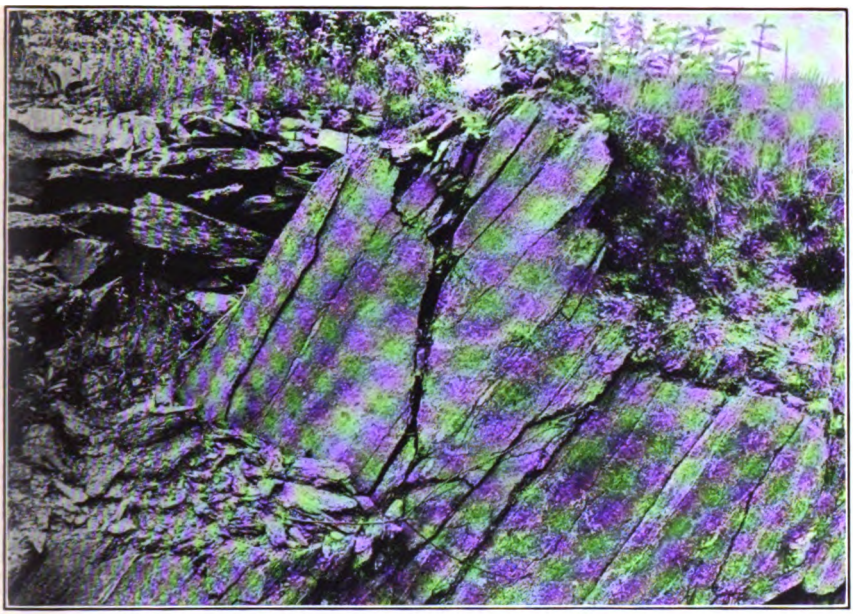
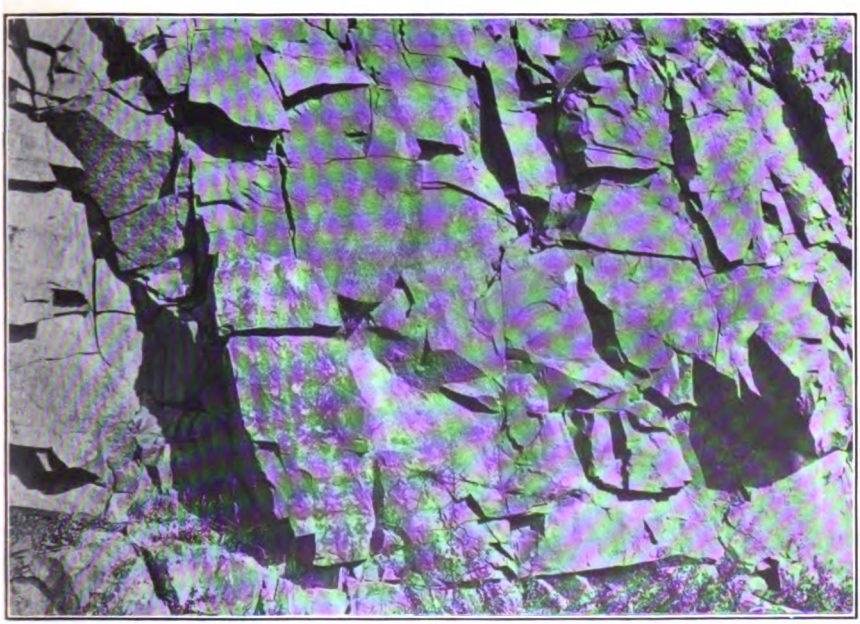


A. CRYSTALLINE ROCK SHOWING FISSURES, STAMFORD, CONN.



B. TRAP ROCK SHOWING FISSURES, HARTFORD, CONN.

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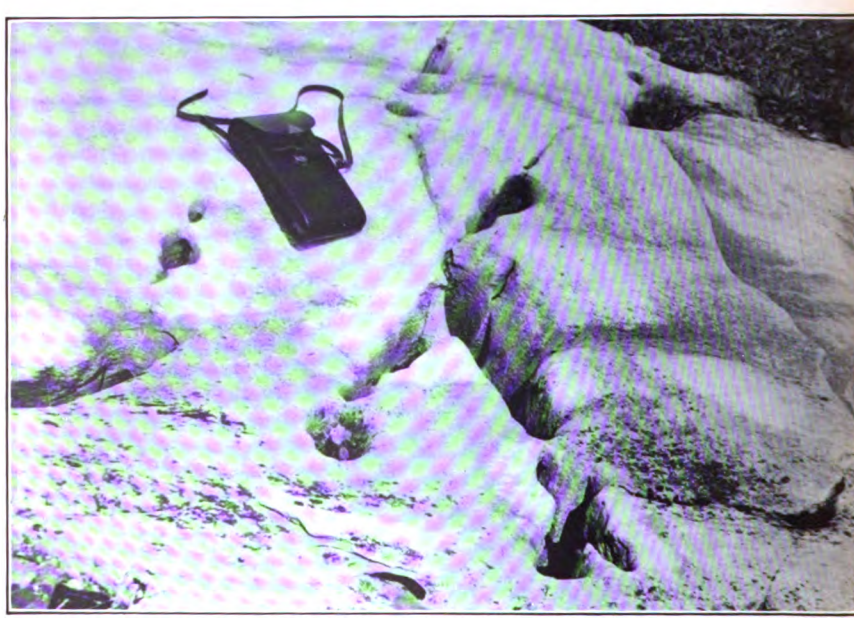
A. SANDSTONE SHOWING FISSURES, HARTFORD, CONN.



B. LIMESTONE SHOWING SOLUTION CHANNELS AT THE SURFACE ALONG JOINT CRACKS, SALISBURY, CONN.

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popularly called "trap rocks," are interbedded with sedimentary formations. As a result of the work of dynamic agencies the crystalline and sedimentary rocks are intensely fractured, cracks being visible wherever the rocks are exposed (Pls. IV, *A* and *B*, and V, *A*). All the crystalline rocks and traps have a very low porosity—less than 1 per cent—and for this reason the circulation of water in them is confined practically to the cracks. Water enters the openings from the overlying drift and passes in the direction of least resistance, down some sloping planes and up others, through vertical cracks, and horizontally through level ones, until it becomes imprisoned in cracks with no outlets or until it reappears at the surface as springs or seepage.

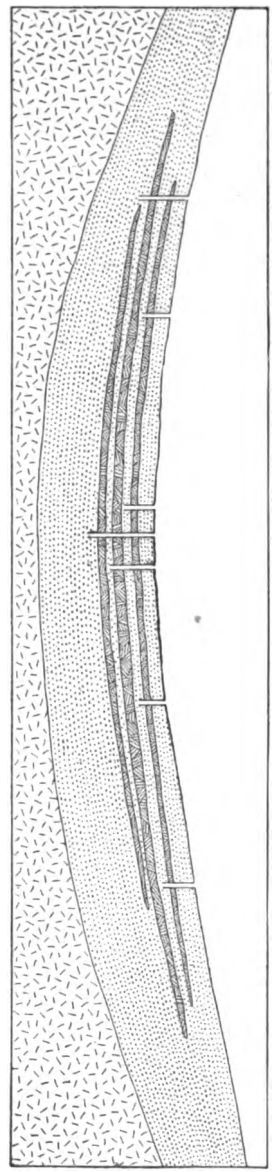

FIGURE 4.—Section of the Connecticut Triassic area as a synclinal basin, showing conditions favorable for artesian wells.

In general, the thickness of the zone of active circulation is nearly equal to the relief of the land surface; that is, openings below the level of the valleys are generally filled with water that is not in motion until wells reach these depths and start circulation by drawing water to the surface. In places, however, these deeper-lying waters are forced by hydrostatic pressure along fault planes or major joints and reach the surface as artesian springs or as artesian wells (figs. 4, 5, and 6).

QUANTITY OF WATER.

The quantity of water in crystalline rocks and traps depends chiefly on the number and size of the cracks. Most of the openings are too narrow, even at the surface, to allow much water to pass, but they are generally connected, either directly or indirectly, with larger fissures into which they drain, and it is the ramifying systems of minor cracks which to large degree regulate the supplies derived from rock borings. The openings in these rocks do not extend to great depths, and their size rapidly diminishes from the surface downward. Nearly all the cracks pinch out entirely within a few hundred

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feet of the surface, and water-bearing fissures at greater depths are rare. As compared with the more porous drift, the crystalline rocks and traps contain little water, the average yield of wells in the crystalline rocks of Connecticut being about 15 gallons a minute. Figure 8 (p. 25) shows the percentage of the wells examined which yield various specified quantities.

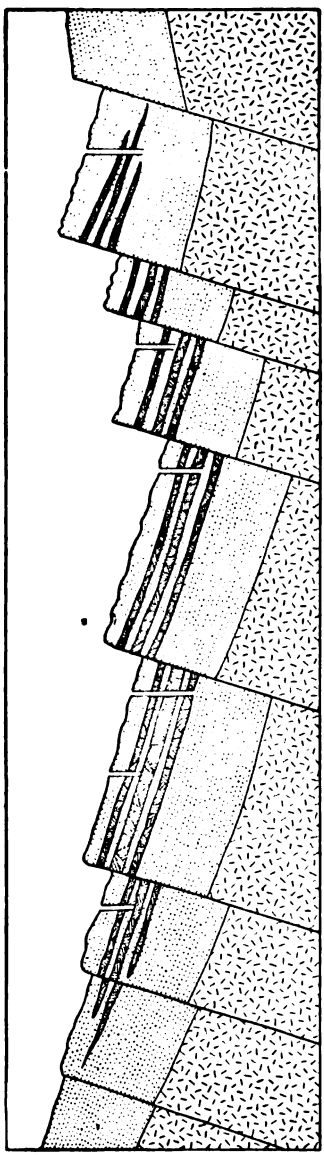

FIGURE 5.—Section of the Connecticut Triassic area as a simple faulted monocline, showing conditions favorable for several small artesian basins.

WATER IN LIMESTONES AND TRIASSIC SEDIMENTS.

CIRCULATION.

The most abundant sedimentary rocks of Connecticut are Triassic sandstones and shales, which occur in the valleys of Connecticut and Pomperaug rivers, and Cambrian and Ordovician limestone (Stockbridge), which occurs in discontinuous patches along the west border of the State from the northwest corner of Greenwich to the Massachusetts boundary. All these sedimentary rocks have been metamorphosed to greater or less degree, and their present texture and structure are such that the circulation of water in them is essentially like that in crystalline rocks.

The average porosity of this sandstone is 20 per cent or more, and its absorptive capacity is about 2 quarts of water per cubic foot, which equals 7 per cent,[1] but most of the water in its pores is not directly available because of the high resistance of the sandstone to circulation. The sandstone is of economic importance as a source of ground water only where fissures are present in which the water may be stored.

[1] Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, p. 105, 1909.

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Fissures are, however, very numerous in the sandstones, and consequently these rocks are an important source of ground water supplies (Pl. V, *A*). The fissures are joints and fault cracks produced by crustal movements and in some places widened by weathering and erosion. The widest fissures are several inches across; the narrowest are mere incipient cracks. They extend from the surface to depths of 300 or 400 feet, and they generally grow narrower from the surface downward. The water in the sandstone, being derived chiefly from the drift at the surface, circulates through the fissures and reappears at the surface at lower elevations as springs issuing from the rock.

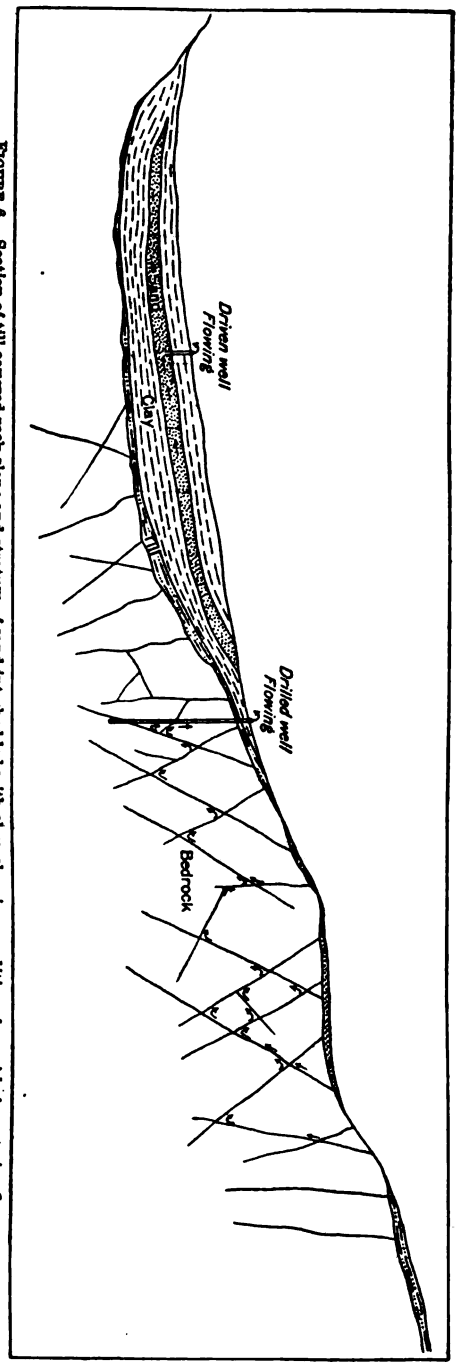

FIGURE 6.—Section of till-covered rock slope and stratum of sand interbedded with clay, showing conditions favorable for artesian flows.

Shale does not occur in Connecticut as uninterrupted beds of wide extent, but in many localities it forms lenses in the sandstone. In general the shale is less porous than the sandstone, and in many places it is entirely impervious. It is important in intercepting and directing the circulation of water in the sandstone, and wells sunk through sandstone usually find water immediately above shale beds. Some of the sandy varieties of shale are, however, more porous than the sandstone, and all the shale is traversed by fissures through which water circulates as in the sandstone.

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QUANTITY OF WATER.

The quantity of water contained in the pores of the sandstones and sandy shales is great, but owing to the minuteness of the pores the quantity recoverable by wells is small. This is illustrated by the well at the Hartford Sanatorium, which was drilled because owing to the altitude of the institution, city water was not available except by pumping. It was sunk to a depth of 974 feet in an effort to obtain a yield of 50 gallons a minute, the minimum amount required. The following table shows the increase in yield as the well was sunk. (See fig. 7.)

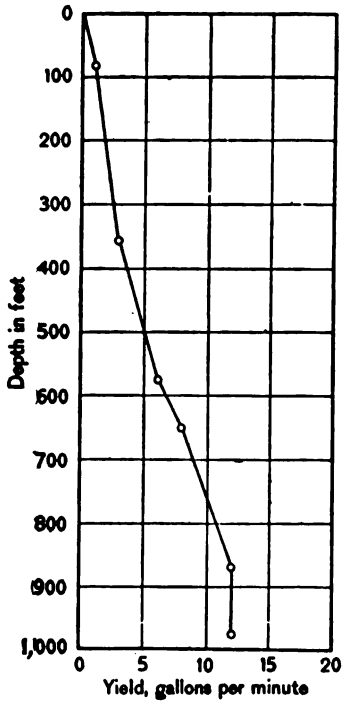

FIGURE 7.—Diagram illustrating increase of yield with depth in well at Hartford Sanatorium.

Yield of Hartford Sanatorium well at several specified depths.

Depth.	Yield.
Feet.	*Gallons per minute.*
85	1
360	3
575	6
650	8
872	12
974	12

Log of Hartford Sanatorium well.

	Feet.
Till	10
Trap	565
Red sandstone	230
Trap	169
	974

In places drills have penetrated to depths of 200 feet or more without encountering water-bearing fissures, and in many of these wells the seepage from the sandstone was so slight that it was necessary to add water from the surface to keep the drill holes wet. No successful wells have been reported in which the water did not come from fissures in the rocks; a considerable number of unsuccessful wells have been sunk in the sandstones which did not encounter water-bearing cracks, and the conclusion is that the porosity of the sandstone, though sufficient for the storage of large quantities of water, is not great enough to afford satisfactory yields by direct seepage into wells. Owing to the ramifying system of joints, however, most of the wells drilled into the sandstone obtain sufficient water for domestic needs. Figure 8 shows the percentage of the wells examined yielding various specified amounts.

The limestone differs from the sandstone in its relation to percolating water only in being much less porous and in being locally

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traversed by joints and solution channels formed by water (Pl. V, *B*). Water enters these passages, joints, or cracks from the saturated overlying material, circulates through them, and eventually issues as springs or seeps back into drift at lower levels. The limestone is so compact that it contains only small quantities of water, and the solution channels by which it is traversed in some places serve as drains through the rock itself and afford a rapid escape for water along their courses; consequently above the valley levels the limestone may become dry very early in a period of drought.

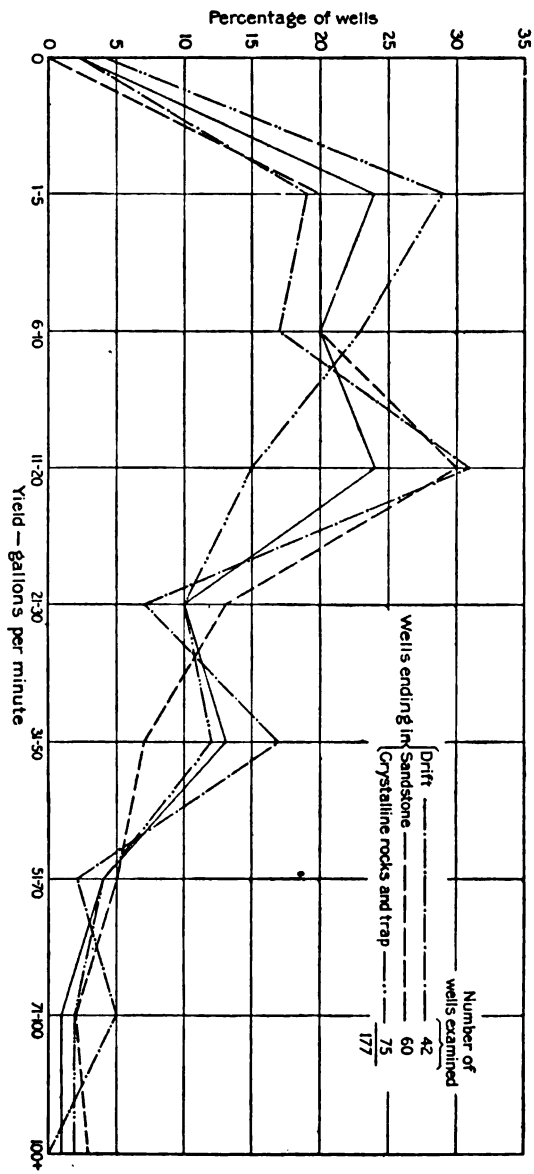

FIGURE 8.—Curves illustrating yields of drilled wells. The solid line shows the percentage yield of the total number of wells examined.

GROUND WATER FOR MUNICIPAL USE.

PROBLEMS INVOLVED.

The problems to be considered in planning the use of ground water for a new or enlarged public water system relate to the quantity of water available, the quality of the water, the methods of obtaining it, and the cost of establishing and maintaining the works. These problems are largely interdependent, and their relative importance depends on the proposed uses of the water and the conditions under which it is to be supplied.

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QUANTITY REQUIRED.

In a town having an established water system the per capita consumption is known and the quantity of water required for extending the system can be estimated with a fair degree of accuracy. In a small town or community in which a public supply is designed to replace private wells an estimate of the amount of water required should be based on a comparative study of the consumption in towns of similar characteristics. Plans for cities or for smaller communities involve consideration of future needs based on the probable rate of increase in population and the circumstances affecting it, and also on the estimated rate and amount of development of industrial enterprises. In a State such as Connecticut, where the significance of past conditions and present trends of population and industries are fairly well understood, an average town of less than 10,000 inhabitants may plan for a 20-year service on the basis of the present population. Estimates of the future needs for larger cities are much less likely to be reliable, and so far as practicable future requirements should be provided by maintaining a system capable of extension at reasonable cost as the need arises. The data available for the larger cities of Connecticut are sufficient to serve as a guide in planning 10 years in advance of present needs on the basis of an estimated consumption of 100 gallons per capita per day.

The factors that determine the quantity of water required are as follows:

1. Number of inhabitants.
2. Nature of the local industries.
3. Wealth and habits of the people.
4. Extent to which water is used in fountains and in lawn and street sprinkling.
5. Climate, as affecting the use and waste of water to prevent freezing.
6. Leakage.
7. Basis of revenue (meter or flat rate).
8. Quality, quantity, and pressure, as tending to encourage or discourage liberal use and great wastefulness.
9. The popularity of a new or improved supply.

The consumption of water is usually stated in gallons per capita per day, but it is not sufficient to take into account only this average daily rate of consumption, for the demand varies during the year and during the day and the supply must be adequate for temporary heavy drafts. The following table shows the average daily consumption in Hartford, Conn., for each month during 1912 and during the period from 1903 to 1912, inclusive:

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Average daily consumption of water during each month in Hartford, Conn.[a]

Month.	1912	Average for 10 years, 1903–1912.	Month.	1912	Average for 10 years, 1903–1912.
	Gallons.	*Gallons.*		*Gallons.*	*Gallons.*
January	8,317,000	6,717,000	July	9,245,000	7,642,000
February	8,730,000	6,959,000	August	8,694,000	7,315,000
March	8,625,000	6,896,000	September	8,675,000	7,411,000
April	8,445,000	7,044,000	October	8,674,000	7,191,000
May	8.800,000	7,380,000	November	8,283,000	6,978,000
June	9,128,000	7,648,000	December	8,142,000	6,775,000

[a] Board of Water Commissioners, Hartford, Conn., Fifty-ninth Ann. Rept. (year ending Mar. 1, 1913), p. 190.

The following table illustrates the variation in the rate of consumption during the day:

Consumption of Mystic water supply in Boston in August, 1893, in gallons per capita per day.[1]

1 to 4 a. m.	40.8	4 to 7 p. m.	79.5
4 to 7 a. m.	58.6	7 to 10 p. m.	61.9
7 to 10 a. m.	103.8	10 p. m. to 1 a. m.	52.9
10 a. m. to 1 p. m.	93.0		
1 to 4 p. m.	98.2	Average	73.6

"The large consumption from 1 to 4 a. m. must have been mostly waste."

To meet these daily peak loads and to insure against emergencies that might arise from fire or disability of pumps, a ground-water system should be equipped with a surface reservoir or a standpipe unless the capacity of the pumps and wells is much greater than the normal consumption.

QUALITY OF WATER.

Most surface waters may be polluted, and pollution of some is practically inevitable. The mineral content of surface waters in Connecticut, however, is seldom such as to render them unfit for general use. Ground waters, especially those drawn from bedrock, may require the removal of iron before they are suitable for use. Therefore the installation of purifying equipment may be necessary, whether the supply comes from the surface or from under ground.

METHODS OF OBTAINING WATER.

PRINCIPAL SOURCES.

The possible sources of water for municipal supplies are streams, springs, deep wells, filtration galleries, and shallow wells. The extent to which each of these sources is employed in New England is shown in the following table:

[1] Turneaure, F. E., and Russell, H. L., Public water supplies, p. 29, 1908.

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Sources of public water supplies in New England.[a]

State.	Number of public supplies derived from—										
	Surface water.	Surface water and springs.	Surface water and shallow wells.	Springs.	Shallow wells.		Shallow wells and springs.	Galleries.	Shallow wells and galleries.	Deep and artesian wells.	Total.
					Dug.	Driven.					
Maine	53	2	0	12	1	0	0	0	0	2	70
New Hampshire	37	2	0	17	1	2	0	0	0	2	61
Vermont	21	3	0	13	0	0	0	0	0	0	37
Massachusetts	67	2	3	23	20	14	3	6	4	1	163
Rhode Island	12	0	0	0	1	0	0	0	0	0	13
Connecticut	48	9	0	8	0	0	0	0	0	2	67
Total	238	18	3	73	23	16	3	6	4	7	391

[a] Compiled from Baker, M. N., Manual of American waterworks, 1897.

NOTE.—Surface water includes supplies from streams, lakes, and impounding reservoirs.

STREAMS.

Streams afford the simplest means of obtaining water for municipal use. If the minimum daily discharge of the stream available exceeds the maximum daily consumption by an amount sufficient to provide for an emergency draft, the water may be diverted directly into the street mains. If, however, the daily discharge, as determined by measurements extending through a number of years, is not sufficient to meet the daily consumption, storage must be provided. As large streams are generally utilized in disposing of sewage, it is customary to go to the smaller ones for water supplies; hence the most common type of development involves the construction of reservoirs. A useful rule for estimating the storage required is that the amount stored shall be about the same percentage of the total yearly consumption as the total yearly consumption is of the total yield of the drainage basin.[1]

In the highland areas of Connecticut practically all the available ground water of the drift and considerable from crevices in the bedrock returns to the surface along the stream courses. For this reason the most effective method of obtaining this ground water is by constructing a dam in the stream into which it is discharged, and thus forcing it to the surface; and since in many places a reservoir site can be selected from which water can be delivered by gravity, the cost of pumping may be eliminated.

SPRINGS.

Springs may be grouped into two classes, the first including those which serve as outlets for ground water that has reached horizons far

[a] International Library of Technology, vol. 36, Water supply, p. 1322.

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below the earth's surface, and the second including those whose water has passed to slight depths only.

Most of the Connecticut springs belong to the second class. In fact, nearly all perennial streams owe their persistence through dry seasons to such springs. Springs of this kind are generally small. They vary in yield with the amount and character of local precipitation and in permanency with the seasonal distribution of rainfall, the extent of their individual collecting areas, and the nature of the soil and vegetation. Most of the small, so-called surface supplies in the State are supported to a large extent by springs of this type, but because of their liability to fail in dry seasons and their average low yield, these springs are not adapted to use as public supplies unless they occur in large numbers and in localities where the surplus yield during wet seasons may be stored for use in droughts. A sufficient number of springs occurring in a favorable locality would produce either a lake or a stream. The accumulated waters from such groups of springs would possess the qualities of surface waters and would properly be classed with them.

Most deep-seated springs are independent of seasonal changes and are free from surface pollution. Their waters may, however, contain sufficient mineral matter to render them undesirable for municipal supplies but valuable medicinally. Springs of this type in Connecticut furnish waters of high purity and are highly exploited for special domestic use. Their commercial value as bottled waters as well as their small number will doubtless continue to prevent their use as sources of municipal supply.

WELLS DRILLED INTO ROCK.

The often expressed idea that a well of water or even a flowing well may be obtained anywhere by drilling deep enough is based on an erroneous conception of the occurrence of ground water. Some areas, as, for example, parts of Texas and South Dakota, are extensively underlain by porous water-bearing rocks capable of furnishing large and continuous supplies, and in such areas it is usually possible, after a few wells have been drilled, to predict with considerable accuracy the depth at which water will be found and the amount that will be obtained. In areas underlain by such materials as comprise the rock floor of Connecticut, however, large quantities of water are seldom obtained by drilling into bedrock, and moreover the yields of new wells can not be predicted from the records of existing rock wells because the supplies are obtained from discontinuous and irregular fissures which vary in size, distribution, and water content.

Wells that overflow at the surface are not common in Connecticut, but flows have been obtained both by drilling into bedrock and by

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driving "points" to shallow depths in the drift. Such flows are generally under low head and may cease within a few days or even within a few hours.

In drilled wells the flow is due to conditions illustrated in figures 2, 4, 5, and 6. If an impervious stratum of clay or till covers a sloping rock surface it may confine the water in the rock crevices and generate hydrostatic pressure that forces the water to the surface when a well penetrates the impervious stratum. In some shallow wells the conditions are similar. A sloping stratum of sand or gravel confined between beds of clay may contain water under sufficient pressure to force the water to flow at the surface when the upper impervious layer is penetrated by a driven point.

As conditions favor flowing wells in but few places in Connecticut, ground water must generally be recovered by pumping. Moreover, in most drilled wells the water does not rise to a level within the suction limit, and a gang of drilled wells can therefore generally not be pumped by means of a suction main. A lift pump is usually required in each well except where air lifts can be used to advantage. On account of the small yields, high costs, and great uncertainty in regard to every phase of the development, drilled wells are hardly to be considered for supplying water to large municipalities. For a village in which the consumption does not exceed 50,000 gallons a day and surface water is not readily available, a satisfactory supply may be obtained by drilling one or more wells into rock.

DUG WELLS.

Dug wells draw their water from the glacial drift. They are best adapted to areas where the drift is not very porous and yields water only slowly, whereas driven wells are best adapted to areas in the valleys where deposits of porous stratified drift supply water more freely. The yield from a dug well depends on the porosity of the drift, the dimensions of the well, and the depth to which the well is sunk below the water table. To obtain permanent supplies these wells must pass below the lowest position of the water table. Dug wells are not adapted for furnishing public supplies unless the quantity of water required is small, and even then such a supply would hardly justify the installation of the necessary pumps and pipe lines, because the cost would be great for each unit of water developed.

INFILTRATION GALLERIES.

Underground galleries or tunnels are usually constructed for the purpose of filtering stream waters. Under favorable conditions they may be used to recover ground water, but in general wherever the deposits are porous enough to yield much water to infiltration galleries, the supplies can be obtained more economically and satisfac-

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torily by means of driven wells. Infiltration galleries are expensive to construct, and their efficiency is subject to decreases which are not easily remedied.

DRIVEN WELLS.

GENERAL CONDITIONS.

The larger stream valleys, as, for example, the valley of Connecticut River near Hartford and that of Willimantic River between Willimantic and Norwich, contain deposits of coarse sediments that are capable of yielding sufficient water for city and village supplies. Even the less extensive deposits, such as are found in the valley of Noroton River, would yield enough water for the smaller villages conveniently situated. The most economical method of utilizing the water from these deposits is probably by means of driven wells with perforated iron casings, 6 or 8 inches in diameter, as described on page 40. A project involving the use of driven wells differs from one in which drilled rock walls are to be used in that reliable information regarding the quantity and quality of water available can be obtained at moderate cost. The thickness and extent of the water-bearing formation can be determined by rough surveys, and pumping tests by means of drive points will establish the feasibility of the project. It does not seem probable that the largest cities of the State could be adequately served by ground-water supplies, but it is certain that many communities requiring water in moderate quantity could economically obtain it from this source, and the large cities could probably supplement their supplies. The use of driven wells is illustrated by the plants at Brookline, Mass., Brooklyn, N. Y., and Plainfield, N. J.

PLANT AT BROOKLINE, MASS.

The municipal pumping plant at Brookline, Mass., has been described by the superintendent, Mr. F. F. Forbes, as follows: [1]

The material for this paper was gathered from work which was done under my direction in Brookline, two and four years ago, to increase the water supply of this town.

The work consisted in laying a suction main made up as follows: 2,054 feet of 24-inch pipe, 2,093 feet of 20-inch pipe, 531 feet of 16-inch pipe, 1,427 feet of 10-inch pipe, and 155 feet of 8-inch pipe, a total of 6,260 feet, and driving 201 2½-inch wells, and connecting 160 wells. The other 41 wells were failures.

The plant was designed to deliver water at the rate of 5,000,000 gallons per day for as many hours each day as might be necessary to supply the town. A slight study for such a plant will convince one that it is very important that the pipes and connections should be air-tight and so put together that they will remain in this state even if some small settling should take place in the suction main, for not only does it cost money to pump air from which no benefit is received, but its presence in the conducting pipes lessens the amount of water they will carry, also decreases the quantity

[1] Forbes, F. F., Driven wells at Brookline, Mass.: New England Waterworks Assoc. Jour., vol. 11, No. 3, p. 195, Mar., 1897.

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which can be taken from the ground by partially destroying the vacuum, and also causes the pumps to perform badly unless the air is removed before it reaches them.

It is not an easy matter to lay a long line of pipe, drive and connect numerous wells, and leave no place through which the air can flow. Not only must the material used be without defects, but the work must be most faithfully done—the latter being by far the most difficult part. It is with much satisfaction that I can speak of the results obtained in Brookline. The plant has now been in use nearly two years without giving the least trouble from air leaks, or, in fact, from any other causes.

A description of the principal details of construction is as follows: The 24-inch suction main is connected directly to the pumps without an air separator or sand receiver. The top of this main is laid from 6 to 8 feet below the surface of the ground, and about 5 feet below the usual level of Charles River during the summer months. The main was laid at this depth for two reasons—first, that more water might be drawn from the ground, and second, that the main might be in the most favorable position not to be affected by expansion or contraction due to changes of temperature. The main has a slight pitch from the pump, the farther end being about 6 inches lower. This construction is necessary to allow any air which may be in the pipes to flow toward the station and not pocket at any point on the line.

This suction main is composed of ordinary cast-iron bell and spigot pipes, laid in the usual way with lead joints. Extra pains were taken, however, in calking these joints. During the laying of this main and the connecting of the wells it was necessary to keep a 6-inch rotary pump running day and night to free the trench from water. The bottom of the trench was a rather fine sand, and the pipe was supported on a blocking reaching to a timber platform, placed about 8 inches below the bottom of the pipes, to allow room to calk the joints.

Short cast-iron Y branches of special design were placed in the main for each well. The 2½-inch outlets of these Y branches were drilled and tapped to a templet at the foundry before tarring, under the watch of an inspector.

The wells were connected to these Y branches by two lead connections 2½ inches in diameter and of a weight of 11 pounds per foot. A gate with companion flanges was placed between these lead connections, the flanges forming the union joint between the wells and suction main. The soldering nipples used with the lead connections were made to order and of the best steam metal. They were delivered untinned in order that any defect in them could be easily found. Special care was taken to solder these nipples to the lead connections. A wiped joint was not considered to be always air-tight, and of this size rather difficult to make, and we finally decided to sweat the nipples in, as this process is sometimes called. The necessary heat was obtained from cast-iron plugs heated in a portable forge which fitted loosely into the nipples. The well pipes were screwed together with special wrought-iron couplings until the ends butted, and special cement was used on the threads. The wells were from 35 to 95 feet deep. Two and one-half inch tees of a special pattern were placed on the wells at a proper grade to allow them to be connected by means of the lead connections to the suction main. The piping of the wells was carried to the height of about 1 foot above the surface of the ground and capped with a special cap. The wells have open ends, no strainers of any kind being used. In the bottom pieces there are five rows of holes with nine holes in a row, spaced 2½ inches apart from centers, and bushed with three-eighths inch brass pipe.

As before stated, we have had no air leaks so far, and as the suction pipe is laid with lead joints, and the connection between this pipe and the wells with lead pipe, thus making the whole construction flexible, we can see no reason why air leaks should ever occur.

The details of the cost of construction of the work done two years ago, which included laying all of the 20, 16, 10, and 8 inch pipe and driving 159 wells, are as follows:

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The cost of driving and connecting 118 good wells and driving and pulling up 41 poor wells:

Labor, driving wells	$1,561.00
Labor, connecting wells	210.00
Labor, pumping out wells	369.00
Well pipes, not including the bottom piece	572.06
Bottom pieces	196.23
Preparing the bottom pieces	118.00
Gate tops for the wells	360.37
Gates	660.80
2½-inch tees	94.40
Soldering nipples	250.16
Solder	23.00
Three-quarter inch rope	5.31
Oil	6.25
Red and white lead	23.59
Lead pipe	333.40
Making lead connections in the shop	52.50
2½-inch plugs	2.29
2½-inch couplings	155.40
Pulling up poor wells	80.00
Akron pipe for gate boxes	306.92
Cutting threads on pipe	206.72
Teaming	14.00
Miscellaneous	51.26
Total cost of wells	5,652.66
Number of feet of good wells driven	5,977
Number of feet of poor wells driven	1,741
Total	7,718
Average depth of the wells ... feet	50
Average number of feet driven per day with gang of four men	50
Cost of labor, driving wells, per foot	$0.21
Average cost of each good well, including driving and connecting and expense of driving and pulling the poor wells	47.90

Detail of the cost of laying the suction main:

Labor	$10,428.32
Lumber	1,118.55
Pipes	6,248.07
Gates	341.16
Lead	515.09
Pumping, the engineer	458.56
Pumping, coal	174.71
Unloading pipes	39.00
Inspecting pipes at foundry and at the cars	183.00
Rubber boots	210.00
Shovels	52.00
Carting men to and from work	947.30
Hauling the pipe from the cars	300.00
Miscellaneous expressing	79.30

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Oil for the engine	$4
Jute packing	12
Miscellaneous	155
Total cost of laying the pipe	21,268.0

The amounts laid are as follows:

20-inch pipe	feet	2,02
16-inch pipe	do	551
10-inch pipe	do	1,420
8-inch pipe	do	155
		4,149

Total cost of laying the pipe	$21,268.03
Total cost of driving and connecting the wells	5,652.66
Total cost	26,920.69
Total cost of laying the pipe, driving and connecting wells, per foot of suction main	6.45

PLANT AT BROOKLYN, N. Y.

The city of Brooklyn, N. Y., obtains a large part of its water supply from gangs of driven wells situated at several places on Long Island. The wells first driven were of the closed-end type, but those sunk later are of the open-end type. The wells are arranged in two rows, one on each side of the suction main, the wells in some gangs being in files and in others staggered. One of the new plants is described as follows: [1]

The main suctions are about 2,340 feet long, with a fall of 12 inches from center to each end. The 62 wells are staggered along the main suction pipe, 12 feet from it and 75 feet apart on each side. Their average depth is 45 feet, a stratum of fine sharp sand being met with at that depth. The outside casing is 4½ inches, with a 6-foot strainer, 2-foot sand pocket,[2] and 6-inch point. Suctions are 3 inches in diameter and 28 feet long. Lateral branches are 3½ inches, and each is provided with a gate. It is expected to get 6,000,000 gallons from this station. The contract price for the last 25,000,000 was $167,250 for sinking and connecting wells, the yield to be determined by a test lasting one year and taken as the lowest average for five consecutive days.

PLANT AT PLAINFIELD, N. J.

The system of driven wells supplying the city of Plainfield, N. J., is described by L. L. Tribus [3] as follows:

The region itself is a comparatively level valley, some 7 miles long and from three-fourths to 2 miles wide, is fairly well wooded, and slopes gently to the westward. It is divided by a small stream running to the southwest, having several short tributaries; together they furnish excellent surface drainage for the city.

[1] Turneaure, F. E., and Russell, H. L., Public water supplies, p. 308, 1909.

[2] A sand pocket is a drum or box inserted in the suction pipe to catch sand that is drawn up with the water. It is provided with handholes to facilitate cleaning.—A. J. E.

[3] Tribus, L. L., Am. Soc. Civil Eng. Trans., vol. 31, No. 700, pp. 371 et seq., 1894.

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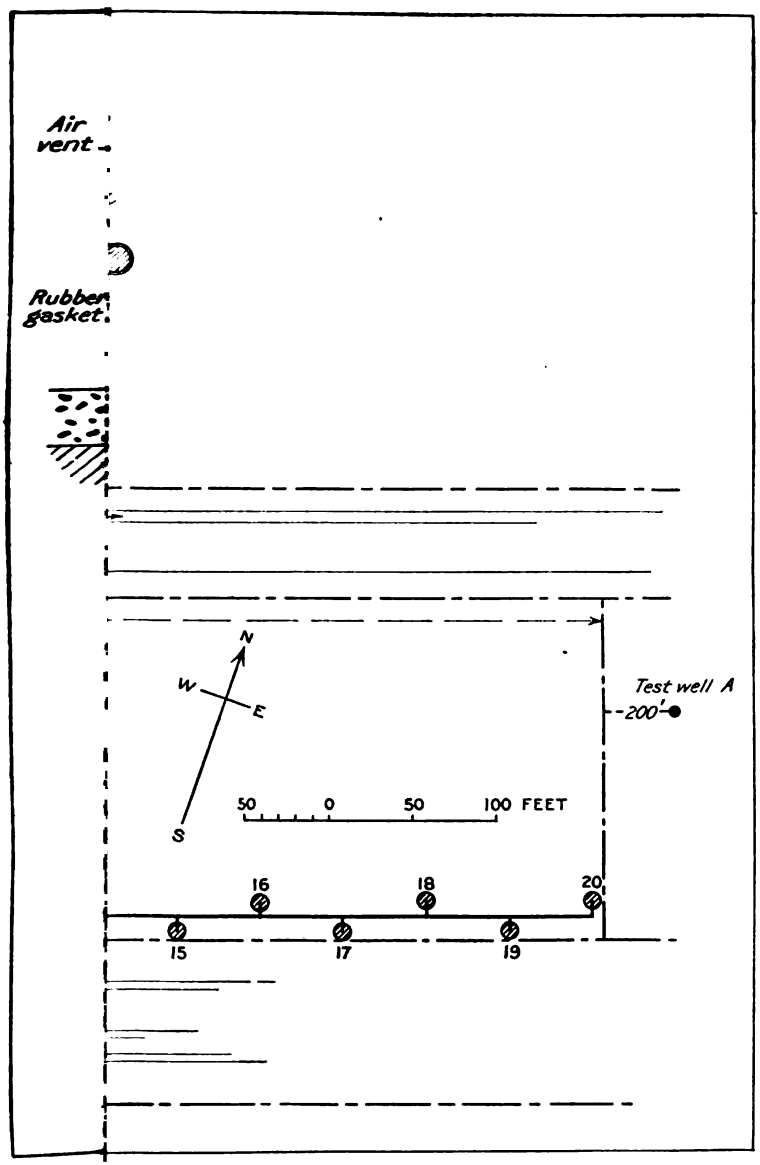

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The soil consists mostly of sand, clay, and gravel strata, rock not being encountered except at considerable depths.

It has always been an easy matter to procure water in abundance for domestic use by driving pipe wells from 20 to 80 feet deep at each residence and attaching pumps directly thereto; and for fire supplies, sinking large brick curbs some 15 or 20 feet into the gravel gave an abundant flow. But obviously, with the increasing population and no sewerage system, individual wells became a source of danger to health, yet for nearly 20 years no definite result was accomplished, more than the mere organization of a private water company.

In 1890 active measures were taken and tests and examinations made, which finally resulted in the sinking of pipe wells on a plot of ground 1½ miles east of the center of the city in a soil where the upper clay stratum was some 30 feet or more in thickness, underlaid by a very coarse water-bearing gravel. This spot was selected for its freedom from probable contamination on ground slightly higher than the city, which at the same time was convenient.

Several test wells were sunk at various points previous to the observations of the writer, and pumping tests made with a low-lift pump of a number of the main wells then driven, under the care of Mr. Rudolph Hering, M. Am. Soc. C. E. The quantity of water obtained from 10 wells for periods of eight hours' daily consecutive pumping, during two weeks of observation, was at the rate of from 2,000,000 to 2,125,000 gallons in 24 hours.

An inspection of Plate V [VI in the present report] will show the final arrangement of the wells, test wells, pumping plant in general, and details of the well tubes. The construction of the cast heads is such as to transform each water tube into practically an open well, giving atmospheric pressure free play rather than forcing its action through the earth, as in systems where but a single tube is used. The most distant well is 500 feet from the pumps and shows in an interesting manner by the vacuum at the well head and increased vacuum at the pump the effect of long suction and friction in the main.

The 2-inch pipe test wells, marked "A," "B," "C," and "D" on Plate VI, were observed daily by the writer, while resident engineer, during several months. They each had a simple balanced float gage and scale, which indicated the rise and fall of water level. They were all very sensitive to draft on the main wells when pumping was going on, though the nearest was 200 feet from the line of wells.

Comparison of these observations under the different conditions and seasons showed, among other things, that in about 1,900 feet the underground water level fell to the westward about 3 feet, or at about the same rate as the average surface of the ground. This evidenced conclusively that the flow of water was toward the city with a head sufficient to prevent any back flow of contaminated waters from the city.

In summary, the plant consists of 20 wells, 6 inches in diameter, from 35 to 50 feet in depth each, ranged in a double row on a strip of land 25 feet wide and 1,000 feet long, having in each a 4½-inch open-end suction tube, connected with a wrought-iron main varying from 8 to 12 inches in diameter. This main is in two sections, each 500 feet, connecting 10 wells.

Two compound surface-condensing duplex-plunger pumps, Worthington make, one of 3,000,000 and one of 2,000,000 gallons daily capacity, and a boiler plant of sufficient power, with various essential small machines, are housed in a rough stone building, slate roofed.

The water, drawn, as before stated, direct from the wells, is pumped into a wrought-iron standpipe (situated near at hand) 25 feet in diameter and 140 feet high, through a 20-inch interior tube rising 5 feet above the top. Two lower openings on this rising main, with valves operated from the outside spiral staircase, afford opportunity for filling the standpipe at lesser head if required.

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The object of this interior tube, which was almost unique when erected, is threefold:

First, by its fountain action, enforcing complete aeration.

Second, complete circulation.

Third, to afford instant fire pressure, no matter what the elevation of water in the main tower. This is accomplished by opening a by-pass, not otherwise used, connecting the rising main and the distribution line, the city's supply being drawn regularly from the bottom of the standpipe with pressure due to level of water in main tower.

From the standpipe the Plainfield pipe system extends to the west, comprising some 30 miles of mains from 6 to 16 inches in diameter, having fire hydrants spaced about 11 and valves 6 per mile. * * *

After the tests made by Mr. Hering and the partial completion of the works, various other tests were made with the permanent pumping plant. It was found that the wells on the westerly line yielded more abundantly than the easterly ones, under equally good conditions, and gave a lower vacuum for the same quantity pumped. * * *

The tests were made with the large pumps, under both free discharge and full working head, singly and together, and drawing from the wells in groups of 5, 10, 15, and 20, using each combination of 5; also, by cutting off one by one until the smallest number that could be used was reached, then adding one by one in reverse order until the full series were again in use. Five wells were found to be the smallest number possible to use and run the pumps smoothly. Wells Nos. 6 to 10 gave the best results, while Nos. 16 to 20 furnished but little water. The best results were obtained for a full flow by using Nos. 1 to 15, inclusive. * * *

During the long-continued dry weather of 1891 the water level became so low that difficulty arose with the extreme suction lift obtained, from 20 to 28 feet, according to rate of pumping, a fall of some 6 or 7 feet since the earlier observations, so that in the summer of 1892 it was deemed best to lower the pumps, which was done to the depth of 8 feet 1 inch below the former positions.

For the sake of a constant observation and record, a 3-inch open tube was driven from the engine room into the water-bearing gravel, and a permanent float gage suspended in it, indicating by a balance pointed on a scale of feet placed conveniently in the room. Although some 80 feet from the nearest main well, therefore not showing the lowest level of the water at the wells when pumping, it does show the relative water level under the same conditions and the daily and monthly range. When pumping the average lowering of the gage is about 8 inches, with an almost immediate return after stopping the pump.

Rainfalls need to be exceptionally heavy to make any marked showing in the water level, and not much then inside of 24 hours. This seems to indicate that the water supply comes from a distance, but there is an insufficiency of data for determining this interesting point.

In these two years or more of operation the wells have furnished daily, without difficulty or signs of falling away, the full demand of from 200,000 gallons at the start to 1,700,000 gallons at the present time, apparently derived, as the early tests indicated, from the western 15 of the 20 wells driven. The water itself has been of uniformly excellent quality, both for domestic and manufacturing purposes—so far, therefore, a decided success as an underground water supply.

PRIVATE SPRINGS AND WELLS.

Many of the wells in Connecticut were dug long before modern principles of sanitation had become established, and having been so long regarded as admirable relics of earlier days they are, naturally enough, imitated now, even at the expense of sanitary and economic considerations; indeed, nearly 80 per cent of the wells in Connecticut

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are of the old dug type, stone lined and, if covered at all, provided with loose, leaky curbs.

Sanitary precautions are necessary not only in caring for dug wells but also in caring for springs and drilled wells. Springs are especially susceptible to pollution because the water issues at the surface and almost always on a slope where surface drainage can readily enter the pool. Springs should be equipped with concrete reservoirs and should be kept covered, and the water should be drawn from delivery pipes. Such equipment is not necessarily elaborate or expensive. It is important only to exclude surface drainage and prevent contamination either by persons or animals, and it should be borne in mind that contamination is possible whenever access to the stored water is possible. Drilled wells properly constructed by reliable drillers exclude surface water. If the well casings are properly set and the pump fittings are tight, such wells are in little danger of pollution.

The per capita consumption of water from private wells is much less than that from public systems, largely because of the general lack of convenience in well equipment, and consequently the quantity of water that will be required in any particular case will depend on the equipment to be installed. A pneumatic system or a tower system installed for the purpose of furnishing running water in the house and barns will require about ten times as much water as a plant consisting merely of a hoisting bucket or a small hand pump. The type of well to be used should also be taken into account. An ordinary dug well yielding continuously only 2 gallons a minute might, because of its storage capacity, meet a temporary draft of 50 or 100 gallons a minute, whereas a driven well, having no stored supply, could not meet a draft in excess of its maximum yield. Therefore the estimate of the quantity required should be based not alone on the total quantity of water used in a day but in part also on the greatest rate at which it is to be pumped from the well.

The water delivered by springs is, in general, of the same quality as the water to be obtained from shallow wells in their vicinity. Therefore the choice between utilizing a spring and sinking a well depends on the relative cost and the resulting convenience. Springs so situated that water may be delivered to buildings by gravity afford very desirable supplies, but springs which must be pumped to be of service give no better supplies than dug wells.

So far as their mineral quality is concerned, well waters are suitable for all ordinary domestic purposes. Dug wells generally yield satisfactory domestic supplies, but they should be carefully curbed, and, if they are open to the air, they should be cleaned out at regular intervals.

Where the unconsolidated material consists of sand or gravel, driven wells are likely to be most convenient, because they are

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especially adaptable to uses in gardens, pastures, barnyards, and other places where water is required for stock and plants and where dug wells would be objectionable. Two or three screen points driven at convenient places in a tobacco field may pay for themselves in a single season by obviating long trips for water.

The water from driven wells is similar in composition to that from dug wells, as it comes from the same source, and it is to some extent susceptible to pollution. The ground around the top of driven wells should be kept clean and dry.

Drilled wells commonly yield at least 2 or 3 gallons a minute, a quantity adequate for the needs of most households (fig. 8, p. 25), and ordinarily the water is suitable for domestic uses.

METHODS OF DEVELOPING GROUND-WATER SUPPLIES.

DRILLED WELLS.

Construction.[1]—Two general methods of well drilling are employed in obtaining water supplies—the percussion method and the abrasion method. In Connecticut the percussion method is most commonly used. It consists of lifting and dropping, by means of suitable apparatus, a heavy string of drill tools which punches or cuts a hole through the unconsolidated materials and breaks the solid rock into fragments small enough to be readily removed from the hole. When drilling in unconsolidated material iron pipe or well casing as large in diameter as the hole will admit, usually either 6 or 8 inches, is generally driven down as rapidly as the drill descends, each added length of casing being securely screwed to the preceding one to make a tight joint. If the well penetrates bedrock, the casing is driven a few feet into the rock to prevent infiltration of surface water. If the well ends in loose materials, the casing extends to the bottom of the hole and may be perforated or slit at the lower end to admit water more readily. The casing is allowed to extend several inches above the surface of the ground to prevent inflow of surface water, and a flange is fitted to the top, to which a pump is attached.

In drilling by the abrasion method hollow drill tools armed with some harder materials, such as diamonds or chilled shot, are rotated on the rock in such a way that a cylindrical core is cut out and brought to the surface in short pieces. The walls sunk by this method are finished in the same way as those made by percussion drilling.

Drillers differ in opinion as to the relative efficiency of these two methods, the points of contention being that the abrasion method is more expensive, and that the rotation of the drill tools tends to seal up the smaller veins, thereby affording a comparatively lower

[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, 1911.

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yield than is obtained by percussion drilling. There are no data at hand which bear conclusively on these questions, but the fact remains that both methods are used, the percussion method to a much larger extent, and good results are obtained by each.

Cost.—Owing to the competition among well drillers there is no uniform scale of prices for drilling wells. The minimum prices charged range from about $1 to $4 per foot, including the casing. Usually the minimum price is charged for the first 100 feet and an additional charge of about $1 per foot is made for each succeeding 100 feet or fraction thereof. Other factors which affect the prices are the character of the bedrocks and depth of the unconsolidated materials, the accessibility of fuel and water for the engines, and the distance from the well to suitable boarding places for the drillers.

No reliable driller will guarantee to obtain water within a given depth. Sometimes a driller offers to obtain a certain quantity of water for a stated sum, but as no driller can predict the depth or location of a successful rock well, such arrangements amount to little more than games of chance in which the advantage is largely with the driller.

Quality of water.—Drilled wells are usually protected against contamination, but neither the quantity nor the mineral quality of the water can be definitely ascertained before drilling, and consequently an expensive well may be drilled without striking a suitable supply.

Drilled wells that end in the drift at depths of 75 or 100 feet are just as likely to be free from pollution as wells that end in rock and they are less likely to contain undesirable amounts of mineral matter. Moreover, drilled wells that end in rock may be polluted, especially where the rock outcrops or lies a short distance below the surface, by the entrance of infected matter through open fissures. Many rock wells situated near the coast are contaminated by salt because some of the fissures intersected by the well connect with the ocean. The contamination is not so easily detected if the fissures contributing to the water supply come to the surface in barnyards or in the beds of polluted rivers. It is not necessarily fortunate if a well strikes a vein of "sulphur" water, because odors not easily distinguished from "sulphur" may be due to pollution. The origin of any odors, colors, or tastes should be investigated before a water is used. Even deep drilled wells may be contaminated in a thickly populated community unless the protective cover of clay is thick and the casing is tight and fits tightly into the drill hole.

Improvements.—Drilled wells which end in the drift do not differ essentially from driven wells and they should be finished in the same manner (p. 40). The casing should be perforated or slit at the principal water-bearing horizons and for some distance above the

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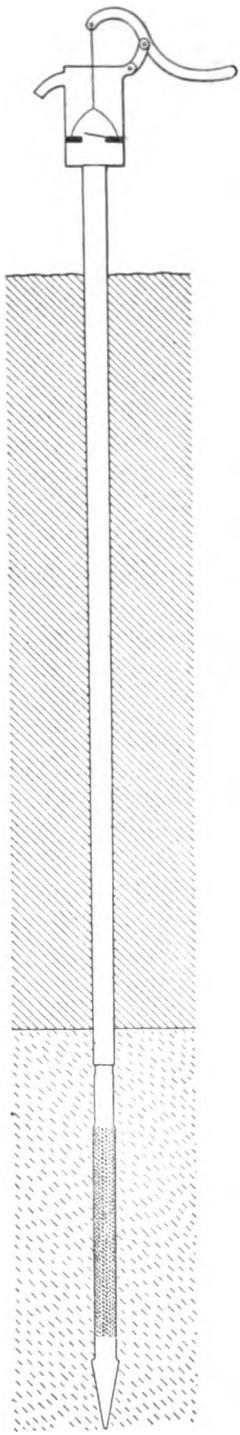

FIGURE 9.--Diagram of driven well.

lower end. By this method the yield may generally be materially increased.

Some wells which produce water of an undesirable mineral character may be improved by casing off the mineral water and drawing from a different water-bearing bed. This method is not likely to be generally successful in Connecticut, however, because at any one locality the quality of the ground water at one horizon does not differ greatly from that at another.

If the yield of a well is reduced by pumping from other wells in the vicinity, the pump cylinder should be lowered, and if this does not recover the yield, deepening the well may do so. But there is likely to be more or less permanent interference when a number of wells are drilled close together. A method of increasing yields of drilled wells which has not been sufficiently used to warrant recommending its general adoption consists of exploding a charge of nitroglycerin or dynamite at the bottom of the well, in order to open radiating fissures that may tap otherwise unavailable water veins. This method is used extensively in improving oil wells, and under favorable conditions it might be equally successful in water wells. The advisability of trying this method before abandoning dry holes ending in rock is suggested. It is not recommended for wells ending in drift.

DRIVEN WELLS.

Two general types of wells are classed as driven wells—the closed-end well and the open-end well. A closed-end well is constructed by driving into the ground with a sledge or drop hammer a "drive point" and strainer screwed to a piece of pipe. Other lengths of pipe are added and the driving is continued until the strainer penetrates the ground-water stratum (fig. 9). The diameter of the pipe and strainer may be 1 to 4 inches, and the length of the strainer is generally between 1½ and 4 feet.

The open-end well is constructed by driving a casing into the ground and at the same time

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removing the material from the interior by means of a sand bucket or sand pump or a jet of water. If the material penetrated is rather hard it may be necessary to remove it in advance of the casing by means of a heavy sand pump or combination jet and drill, or ordinary drilling may have to be done. A strainer may be attached previous to driving, or it may be adjusted after the casing is down by lowering it on the inside. Where the water-bearing deposits include coarse material and large quantities of water are sought, as for municipal or industrial supplies, the most satisfactory results will be obtained by perforating the casings where water is to be admitted with numerous circular holes at least one-fourth inch in diameter or by slits at least one-fourth inch wide. These perforations can be cut or drilled before the casing is inserted or they can be made by perforating tools after the casing is in place.[1]

After the casing is in place and the perforations have been made the well should be thoroughly cleaned out in order to remove the fine sediments and give the water free access to the well. This can best be done by first using a sand bucket or sand pump and then applying an air lift. If an air lift is not available, rapid pumping with a centrifugal or other pump can be substituted. Strong wells can often be developed by removing large quantities of sand and silt, and thus leaving a thick layer of clean gravel around the intake of the well.

The open-end well is adapted for harder ground and larger diameters than the closed-end well. The use of drive points is restricted to areas in which water can be obtained in rather fine gravel or sand at moderate depths, but open-end wells may be used in almost any unconsolidated deposits and they may be sunk to depths of several hundred feet. It is probable that in Connecticut either drive points or the usual drilled wells ending in the drift and having the casings perforated will be found satisfactory.

Driven wells are used to obtain both domestic and municipal supplies. It is seldom that more than one well is required to furnish the desired amount of water for domestic needs, but for public systems for large towns these wells are commonly driven in gangs, arranged in one or two rows along a suction main to which each well is connected by a lateral branch (Pl. VI, p. 34). The most economical system is one in which the suction main can be laid on the surface of the ground, but in some systems, either for the purpose of obtaining the maximum yield or because the water stands below the suction limit of the surface, it is necessary or desirable to lay the suction main in a trench.

[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, pp. 67-69, 1911.

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It is not possible to give universally applicable figures in regard to the requisite number of wells and their size and spacing, owing to the diversified conditions under which such plants are used. But in general the line of wells should be at right angles to the direction of underflow, and the distance between the wells from 15 to 100 feet, according to the size of the wells. The number and size of wells to be used will be determined by the quantity of water required, by the thickness and character of the water-bearing formation, and by the results of pumping tests to determine the permeability of the formation.

One of the principal difficulties encountered in the operation of driven wells is clogging. Infiltration of fine sand or incrusting of the strainer may reduce the yield of a well materially, and it is necessary, therefore, to keep the tube clean. It is usually advisable to subject a newly driven well to heavy pumping for the purpose of drawing out the fine material adjacent to the strainer. Coarse material will be left in its place, forming a natural screen, which will minimize the tendency to clogging, and the yield of the well will be increased by the consequent increase in the porosity of the material surrounding the screen.[1] When clogging is due to sand only, it is usually possible to remove the obstruction by forcing water into the wells under high pressure or by means of a steam jet, but when the sand is cemented it is necessary to withdraw the strainers and clean them or replace them by new ones.

The liability to pollution of supplies from driven wells depends on the depth from which the wells draw, the effectiveness of overlying clay beds in shutting out polluting matter, the amount of water that is drawn, and other conditions. Though the danger of pollution is less than in open dug wells, care should be exercised in selecting the sites and in protecting the surroundings. Supplies such as those required for large municipalities may be in danger of drawing polluted water from near-by streams, although small supplies drawn from the same wells might not be in danger of pollution.

INFILTRATION GALLERIES.

Infiltration galleries are trenches or tunnels with sides and roofs constructed usually of masonry or concrete and the floors made to admit water. Galleries may be built in the banks or beds of streams to intercept the underground water as it approaches the streams. The deposits in filled valleys are saturated below the level of permanent streams, and galleries in such deposits offer practicable means of obtaining water. The bottom of a gallery may profitably be made lower than the bed of the stream to insure maximum infiltra-

[1] Meinzer, O. E., Geology and underground waters of southern Minnesota: U. S. Geol. Survey Water-Supply Paper 256, p. 86, 1911.

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tion. Water from the stream itself does not enter the gallery unless the draft on the gallery exceeds the infiltration from the landward side. A gallery is a modified form of dug well, from which it differs essentially only in capacity, and the same sanitary rules apply to both.

DUG WELLS.

The most common well is that made by digging a hole 2½ to 4 feet in diameter and deep enough to obtain a suitable quantity of water. The hole is then walled up from the bottom to the surface of the ground with loose irregular stones and bowlders picked up in the vicinity of the well. Brick laid in mortar and glazed tile have been used for some walls, but these materials, though much more desirable, are more expensive than the stone commonly used. The top of the well is commonly finished by fitting a square curbing of boards over the hole and adding a wheel or windlass for hoisting a bucket. On many wells, however, there are better equipments, ranging from screened well sheds to concrete seals with good pumps. Most dug wells end in the drift, but in areas where the drift is thin they may end at the rock surface or penetrate the rock a few feet, the rock being removed by blasting. The principal advantages of dug wells are the ease with which they may be cleaned and refitted with pumps and their large storage capacity; their chief disadvantages are their liability to pollution and their ready response to changes in the weather.

The following suggestions as to the sanitary construction of dug wells are extracted from the Virginia Health Bulletin, volume 1, No. 3, page 113, September, 1908:

THE ESSENTIALS OF A GOOD WELL.

The location of the well is of the greatest importance. It should be as far as possible from the house, barn, and privy. If possible, the surface of the ground about the well should be a little higher than the surrounding soil, so that any surface washings may be carried away from the top of the well. The ground about the top should be well sodded in grass. This not only adds to the attractiveness of the well but it takes care of a great deal of water that would otherwise have to stand in pools about the well. If the stock have to be watered from the well, there should be a pipe leading to a stock trough not less than 20 feet away, so that the stock need not come up to the well itself.

A well, to be safe, should be not less than 20 feet deep; that is to say, 20 feet from the surface of the ground to the top of the water. It should go well through the surface soil, preferably through a layer of clay. The lining should be of brick or stone laid in cement. Any lining that allows water to seep through it above the surface of the water may lead to pollution. The space between the casing and the surrounding soil should be filled with sand or earth.

The top of the well should be raised from the ground about a foot and set in cement or masonry coping that goes at least 3 feet below the surface of the ground. Over

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the top should be laid a solid, double tongue-and-groove flooring that is absolutely waterproof. This is essential. Most wells are polluted by material that falls in or is washed in from the top, and not by seepage through the soil.

On the well top there should be a good pump, carefully set so as to exclude leakage from around its base. If the pump can not be used, there should be an automatic tipping bucket. The well bucket should not be handled with the hands. Many wells have been infected by handling the bucket with soiled hands and then letting it back into the well, the filth being then washed off into the water.

Below the spout there should be a trough with a pipe leading some distance away, so that the waste water may be carried away from the well.

A well constructed in the manner described above will almost always furnish water that is perfectly safe, and the saving of sickness and trouble will many times overpay for the expense and care involved.

For convenience in discussion, dug wells may be divided, according to their relation to bedrock, into groups including, first, wells that penetrate bedrock; second, wells that just reach rock; and third, those that end in drift.

Wells that penetrate bedrock are sunk in localities in which the drift is thin. The thickness of the water bed in the vicinity of such wells may be less than the normal fluctuation of the water table and, consequently, in times of drought there may be no available water in the drift. But the rock basins generally act as reservoirs for the storage of water which has seeped in from the drift and these wells therefore usually carry small supplies through dry seasons. In cleaning rock wells, and sometimes in digging them, actual veins of water are encountered, and this has led some people to believe that the water is derived from sources deep in the bedrocks. Though such an origin is possible, most of these "veins" are shallow water-filled cracks formed naturally in the rock or produced by blasting. These cracks, radiating from the well, tap all along their courses the saturated zone of the overlying drift, and thus make it possible for the well to drain a much larger area than it otherwise could.

Wells that extend to the surface of the bedrock are usually found in areas of thicker drift than are those which penetrate the rock. Like the rock wells, they pass entirely through the saturated part of the drift, but they do not contain a stored supply and therefore fail if the water table sinks to the rock surface. Consequently in localities where the wells are of both types the supplies of the rock wells last longest in times of drought, although the others, drawing from a saturated deposit whose average thickness is greater, give a greater average yield.

Most of the wells that do not reach rock are found in areas of deep drift. These wells are sunk below the water level to a depth which at the time of digging is considered sufficient to insure the required quantity of water. Most of the wells that fail are of this kind. The failure may usually be attributed to one of the following causes:

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(*a*) The well may be too shallow. To be reliable it should be sunk at least several feet below the lowest water level. This work can be most easily accomplished during dry seasons.

(*b*) The well, originally deep enough, may become "filled in" with sand and mud carried by inflowing water. In this manner the bottom of the well may be raised in wet seasons, when the water table stands high, to a level below which the water table sinks in dry seasons.

(*c*) There may be a permanent lowering of the water table, so that the bottom of the well lies within the zone of fluctuation. This may result from tiling, from a heavy draft on wells, or from lowering surface drainage either by removing dams or by deepening the channels of neighboring streams.

Wells that end in the sand or loose till should be cleaned about once a year; wells that end in the rock may need less

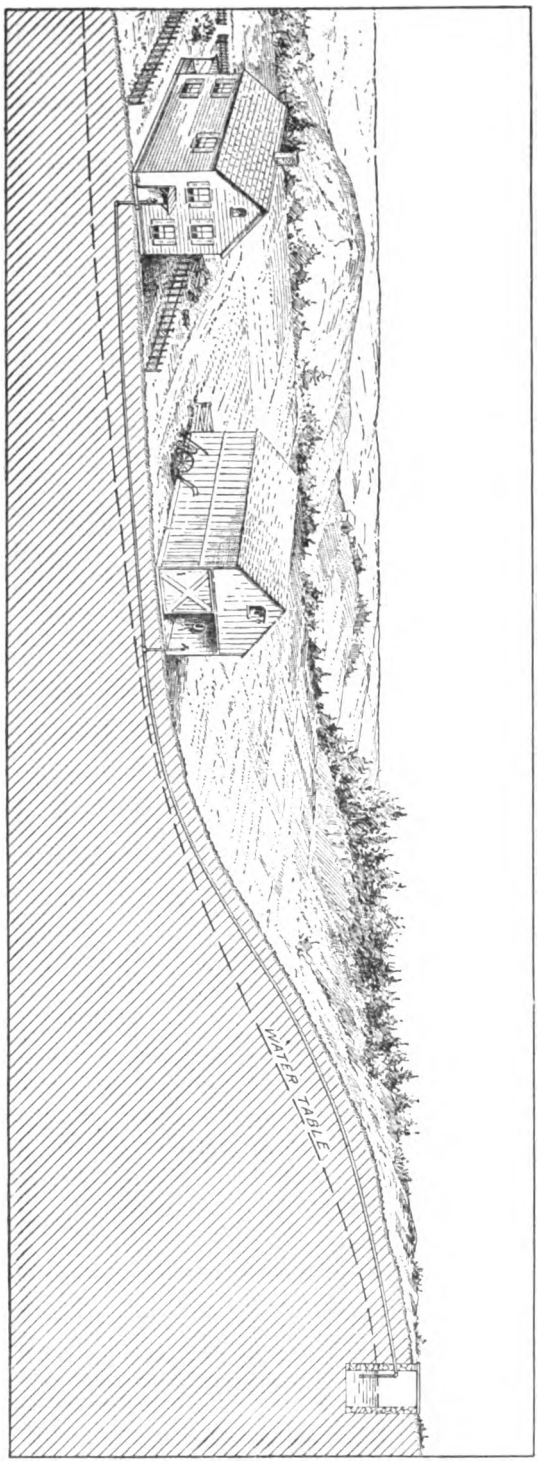

FIGURE 10.—Diagram of siphon well and domestic waterworks.

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frequent attention. In any event cleaning should be the first remedy employed to restore the yield of a well. If this is not effective, then the well should be deepened, and if this is done when the water is lowest it will be easy to judge the necessary depth. Wells may be deepened without disturbing the old wall by sinking 18-inch or 24-inch tiling from the original bottom to the required depth. A method sometimes employed where the well ends in sand consists in driving a "point" (p. 40) into the bottom of the well to the necessary depth. If the strainer is more than 25 feet below the surface of the ground that is, below the suction limit—the pump cylinder may be attached at some point between the surface of the ground and the bottom of the dug well. In some wells, especially those that end in rock, the most feasible way to increase the supply is by drilling from the bottom of the old well. This method amounts practically to sinking a new well except that the cost of drilling to the depth of the old well is saved.

A use of the dug well which is popular in some parts of Connecticut is illustrated in figure 10, the well being sunk on a hillside above the house and barns so that water may be delivered to the buildings by gravity and under pressure. This is an excellent device wherever it can be used.

DESCRIPTIONS OF TOWNS.[1]

HARTFORD.

POPULATION AND INDUSTRIES.

Hartford is in the central part of the State, in Hartford County (fig. 1, p. 12). It is reached by the Highland division and the Springfield and Valley branches of the New York, New Haven & Hartford Railroad, and by the Central New England Railway; by steamboat from New York and Connecticut River towns during open season; by electric railways from Wethersfield, Rocky Hill, Middletown, Glastonbury, East Hartford, Burnside, Manchester, South Manchester, Talcottville, Rockville, East Windsor Hill, Springfield, Windsor, Poquonock, Suffield, West Hartford, Bloomfield, Farmington, Unionville, Newington, and New Britain. Post offices are maintained at Hartford and Parkville.

Hartford was settled in 1635. The Indian name was Suckiage. It was named Newtown, and changed to Hartford in 1637 by an act of the assembly. The city of Hartford was incorporated in May, 1784. The town and city were consolidated in April, 1896. The area is 17.29 square miles, or 11,065.6 acres.

[1] The name "town" applied to 168 minor subdivisions of the counties in Connecticut is equivalent to "township" of the Western States, except that the boundaries of the towns are irregular and their areas unequal. Cities, villages, and boroughs are incorporated communities within the several towns and may have the same name as the town.

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The population of Hartford in 1910 was 98,915. In 1912 it was estimated to be 106,000. The population from 1756 to 1912 is shown in the following table:

Population of Hartford, 1756–1912.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	3,027			1850	13,555	59	
1774	5,031	66		1860	29,152	115	
1782	5,495	9		1870	37,743	26	
1790	4,090		[a] 25	1880	42,551	12	
1800	5,347	30		1890	53,230	25	
1810	6,003	12		1900	79,850	50	
1820	6,901	14		1910	98,915	23	
1830	9,789	41		1912	[b] 106,000	7	
1840	12,793	30					

[a] East Hartford was set off from Hartford in 1783.
[b] Population for 1912 estimated. Connecticut State Register and Manual, 1912, p. 404.

The principal industries are the manufacture of bicycles, blower systems, coil pipes, drop forgings, envelopes, fine tools, firearms, harnesses, knit goods, leather belting, machinery, metal castings, motor carriages, nails, organs, pins, plumbers' supplies, railroad equipment, rubber automobile tires, screws, silverware, typewriters, woven-wire mattresses, and printing and binding.

TOPOGRAPHY.

Hartford lies in the middle of Connecticut River valley, about midway between the Talcott Range on the west and the highlands on the east. The flood plain of Connecticut River occupies the northeast and southeast corners of the town, but elsewhere the topography is moderately hilly, in the south owing to outcrops of trap and, in the north, to drift and sandstone ridges. The average relief is about 50 feet. About one-sixth of the town is more than 100 feet above sea level and about one-third is less than 20 feet. The highest elevation—285 feet—is on Cedar Hill, which extends a short distance into the town from the south. (See Pl. IX, in pocket.)

A small part of the drainage reaches Connecticut River directly, but most of it is carried by Park River, which is formed by the union of Hog River and South Fork just west of the center of the town, the former occupying the north half and the latter the south half of a valley lying along the west boundary (Pl. IX). These streams are small, discharging at times not more than 0.5 second-foot.

WATER-BEARING FORMATIONS.

Bedrock.—The bedrocks underlying Hartford are Triassic sandstones and shales interbedded with trap rocks (Pl. VII). They come to the surface in only a few places in the city but generally lie only a short

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distance below. The trap rocks occur in three sheets, designated the lower, middle, and upper sheets. The middle sheet outcrops in Cedar Hill and the upper sheet outcrops along a line extending southward from Trinity College, but the lower sheet does not appear at the surface in Hartford. Sandstone is exposed in the bed of Park River and at other places in the town. From Connecticut River to the center of the city, a distance of about a mile, the rock surface rises nearly 100 feet, and the maximum relief of this buried surface within the limits of the town is about 360 feet, the lowest elevation being about 75 feet below sea level and the highest 285 feet above sea level.

Both the sandstones and the trap rocks are extensively fractured, and many of the cracks or "seams" contain water.

Till.—The higher hills in Hartford, such as Cedar Hill and the ridge marking the outcrop of the upper trap sheet, are covered with till, consisting of mixtures of sand, gravel, and bowlders, and a small amount of clay or rock powder. In general the till exceeds 10 feet in thickness only in a few rock depressions and on the east slope of Cedar Hill, where in some places its thickness is 20 feet or more. It is therefore unimportant as a water-bearing formation, although small quantities for domestic use might be obtained in the deeper deposits in outlying parts of the town.

Stratified drift.—Most of the material covering the rock in Hartford consists of stratified deposits of sand, clay, and gravel. (See Pl. IX.) The clays, which constitute the principal part of these deposits, occur in beds 20 to 100 feet thick along the valleys of South Fork, Hog River, and Park River, and in a belt about a mile wide along Connecticut River. The clays are regarded as having a high commercial value and are used for the manufacture of brick in the southwestern and in the northern parts of the city. West of the clay deposits the rock is covered principally with sand containing lenses of clay, ranging in thickness, according to the contour of the rock floor, from a mere film to 30 or 40 feet. The occurrence of ground water in areas of stratified deposits is discussed on page 15.

Alluvium.—Near the middle of the eastern boundary of Hartford Connecticut River closely approaches the rock wall, but north and south of this place the channel swings to the east and the rock valley is filled with drift and alluvium. In a number of test borings made through the valley fill near the northeast corner of the city by the Hartford water department, samples of the rock penetrated were taken at intervals of 5 feet, from which the following log was compiled. The first 35 feet of this section is alluvium, the underlying 40 feet of clay is believed to be a lacustrine deposit, and the last 5 feet is probably till.

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CONTACT OF TRAP ROCK WITH UNDERLYING SANDSTONE, HARTFORD, CONN.

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Log of test wells near northeast corner of Hartford.

	Depth in feet.
Fine silt, chiefly sand; some clay with very fine flakes of mica	5
Same as above but larger percentage of clay	10
Same, except larger percentage of sand	15
Do	20
Do	25
Do	30
One-half sand and one-half reddish clay; sand is about 30 per cent mica	35
Clay, reddish color	40
Do	45
Do	50
Do	65
Do	70
Do	75
Do	80
One-half reddish clay and one-half sand with a little mica	85
Very fine grained red sand (sandstone powder)	86

SURFACE-WATER SUPPLIES.

The surface waters in Hartford are not used for public supplies, principally because they are highly polluted. The only water available in considerable quantity is that of Connecticut River. Since 1867 this water has been used by the public system on only a few occasions when, as a result of drought, the quantity in the reservoir became inadequate. The last of these occasions was in the summer of 1900, when the water was distributed without filtration or germicidal treatment through certain sections of the city and a noticeable increase in sickness was attributed to its use. The reports of Dr. John L. Leal and James A. Newlands,[1] however, indicate that with proper germicidal treatment water of Connecticut River could be rendered suitable for municipal use in emergency.

The experiments made in this connection showed that when bleaching powder sufficient to furnish 1 part per million of available chlorine was used the removal of bacteria was always greater than 99.5 per cent and the colon bacillus was not found in the treated water. The cost of thus treating water is less than a dollar per million gallons.

GROUND-WATER SUPPLIES.

Owing to the fact that the municipal system reaches all parts of the city, ground water is little used in Hartford. In the central part of the city several wells have been drilled, most of which are being used, and they yield 8 to 102 gallons a minute and average

[1] Board of Water Commissioners, Hartford, Conn., Fifty-sixth Ann. Rept. (year ending Mar. 1, 1910), pp. 33-42.

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47 gallons a minute. Considerable interference has been observed in these wells on account of their close proximity to each other. Five wells (Nos. 17, 18, 19, 20, 21 of Pl. IX, in pocket, and table on p. 51) were drilled about 75 feet apart at the offices of the Hartford Electric Light Co., but four of them have been abandoned because the combined yield was little more than the yield of the deepest one alone. The abandoned wells are respectively 200, 200, 201, and 228 feet deep. Their yields as reported by the driller were 120, 150, 150, and 200 gallons a minute, respectively. However, on their failure to deliver a combined yield of 100 gallons when in use the fifth well was drilled. This well is 620 feet deep and its yield is 100 gallons a minute. The water is now brought to the surface by means of an air lift. When this well was completed the other wells were so reduced in yield that they were abandoned.

A similar condition was observed in the wells of Long Bros. and Dillon & Douglass. The Long Bros. well was yielding 22 gallons a minute with the pump rods ending 153 feet below the surface until the Dillon & Douglass well, about 250 feet distant, was pumped, the pump cylinder being 235 feet below the surface. The yield of the Long Bros. well was thereupon reduced to only a few gallons a minute, but the original yield of 22 gallons was recovered by lowering the pump cylinder 38 feet.

The water obtained by means of wells drilled into bedrock is drawn from fissures or seams, many of which are small. The supply in one of these fissures is therefore not large and not readily replenished when drawn upon. (See description of well at Hartford Sanatorium, p. 24.) When more than one well taps such a fissure a heavy pumping from one well reduces the yield of the others.

The Hartford water department conducted a series of experiments with 2-inch driven wells to ascertain the possibility of obtaining water to supplement the present system in emergencies. Eighteen wells were driven, some of them in a sand bar in the bed of Connecticut River just above the Highland division railroad bridge and some of them in Riverside Park in a swale about 150 feet west of the river. The depths ranged from 4.5 to 48.5 feet. Steam pumps were operated day and night for testing the flows. The best yields, amounting to about 45 gallons a minute, were obtained at depths of about 15 feet.

The available information in regard to the drilled wells in Hartford is presented in the following table:

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Drilled wells in Hartford.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Depth to rock.
		Feet.	*Feet.*	*Gallons.*	*Feet.*
1	Keeny Park	70	200	42	40
2	Mrs. Louisa H. Sage	50	125	8	30
3	Hartford water department test hole	22.9	88	.....	88
4	.....do	24.9	86	.....	86
5	.....do	23	Between 80 and 90.	.....	Between 80 and 90.
6	.....do	21.4			
7	.....do	22			
8	.....do	20.7			
9	.....do	22.8			
10	.....do	21.6			
11	Ætna Brewing Co	30	400	102	8
12	P. Barry & Sons, Hartford Cold Storage Co	18	400	72	40
13	J. Pilgard	40	205	68	5
14	Dillon & Douglass	50	.....	.....	.....
15	Long Bros	50	.....	.....	.....
16	Allyn House	35	318	50	28
17	Hartford Electric Light Co	40	.....	.....	.....
18	.....do	40	.....	.....	.....
19	.....do	40	.....	.....	.....
20	.....do	40	.....	.....	.....
21	.....do	40	.....	.....	.....
22	Retreat farm	130	180	20	49
23	Jos. Dart	130	74	22	58
24	Goodwin Park	55	251	(a)	29
25	Hartford Sanatorium	160 ?	974	.....	.....

a Well flowing.

MUNICIPAL WATER SUPPLY.

The Hartford water department was organized in 1853 and the first reservoir of the present system was built in 1867. Others have been added from time to time, the total now being six, which have a combined capacity of 2,043,000,000 gallons and drain an area of 10½ square miles along the crest of the Talcott Range (Pl. VIII). The water is delivered by gravity. The mains also pass through West Hartford, supplying most of the homes in that town, and extend into Bloomfield and Wethersfield; altogether a population of about 121,644 receives the water. The total consumption for the year ending March 1, 1912, was 2,938,615,000 gallons; the daily consumption per consumer was 68.1 gallons. The average daily consumption during the month of July, 1911, was 8,450,000 gallons and the average depletion of the reservoir, determined by gage readings, was 8,850,000 gallons. The difference, 400,000 gallons, was attributed to evaporation.

The supply has become inadequate for the rapidly increasing population, and another reservoir, now being constructed on Nepaug River, is expected to increase the storage capacity of the system about 400 per cent, thus making it capable of serving a population of 400,000. The accompanying map (Pl. VIII) shows the newly acquired catchment area and details of the works.

QUALITY OF GROUND WATER.

Analyses of the water from six drilled wells in Hartford indicate that much of the water from the bedrock is high in mineral content and very hard. The wide range of composition is well shown by

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comparison of analyses 5 and 6, which represent, respectively, a soft water of low mineral content and a very hard water of high mineral content, especially high in sulphate. Analyses 2, 3, 4, and 6 represent waters too strongly mineralized to be suitable for boiler use in their raw state and almost too strong for economical softening.

Analyses of water from drilled wells in Hartford.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2	3	4	5	6
Dissolved solids at 180° C	474	916	1,098	1,249	57	1,534
Total hardness as $CaCO_3$	332	450	570	545	32	850
Silica (SiO_2)	18	.....	15	15	.....	16
Iron (Fe)	.30	.10	1.3	.12	.20	.5
Calcium (Ca)	96	157	190	196	.....	286
Magnesium (Mg)	52	28	29	48	.....	57
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	335	136	340	252	31	144
Sulphate radicle (SO_4)	24	486	351	422	12	897
Chlorine (Cl)	40	38	139	213	2.3	20

1. Well of Mrs. Louisa H. Sage (Pl. IX, No. 2), 125 feet deep; sample collected June 17, 1915.
2. Well of Ætna Brewing Co. (Pl. IX, No. 11), 400 feet deep; sample collected June 17, 1915.
3. Well of Hartford Cold Storage Co. (Pl. IX, No. 12), 400 feet deep; sample collected June 7, 1915.
4. Well of Long Bros. (Pl. IX, No. 15), depth unknown; sample collected June 16, 1915.
5. Well at Allyn House (Pl. IX, No. 16), 318 feet deep; sample collected June 16, 1915.
6. Well at Retreat farm (Pl. IX, No. 22), 180 feet deep; sample collected June 24, 1915.

WEST HARTFORD

POPULATION AND INDUSTRIES.

West Hartford (Pl. IX), in the central part of Hartford County, is reached by the Highland division of the New York, New Haven & Hartford Railroad, which has a station at Elmwood, and by electric railways from Hartford, Farmington, and Unionville. Post offices are maintained at West Hartford and Elmwood, and outlying sections of the town are covered to a large extent by rural free-delivery routes. The town comprises an area of 21 square miles. It was separated from Hartford and incorporated in 1854.

The census of 1910 gave the population as 4,808, or an increase of 51 per cent over the population in 1900. The changes in population since 1860 are shown in the following table:

Population of West Hartford, 1860–1910.

Year.	Population.	Per cent increase.	Year.	Population.	Per cent increase.
1860	1,296	.....	1890	1,930	6
1870	1,533	18.7	1900	3,186	65
1880	1,828	19	1910	4,808	51

West Hartford is largely a residential town for Hartford business men. The principal industries are agriculture, in which dairying, tobacco growing, and market gardening are specialties; cultivation of flowers under glass; and manufacture of brick, motor coolers, and water heaters. From 10,000 to 12,000 tons of ice is stored annually for outside markets.

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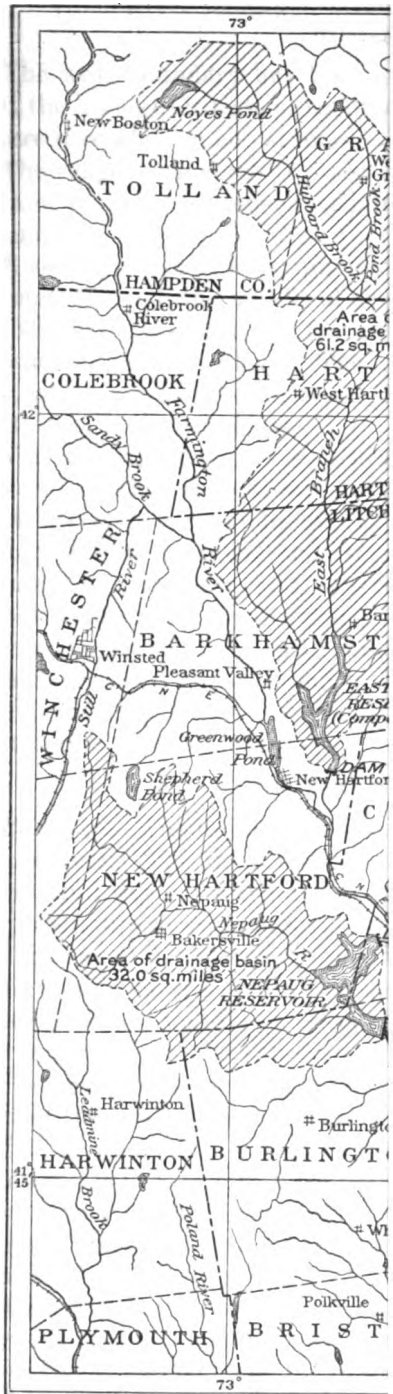

Base drawn from U.S. Geological Survey topographic atlas sheets

MAP SHOWING

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TOPOGRAPHY.

The west boundary line lies along the crest of the Talcott Range and the highest altitude in the town is on this line near its north end, where it reaches an elevation of a little over 800 feet. The east slope of the range is moderately steep and the general level of the eastern part of the town is reached within a distance of 2 miles from the west boundary.

A second range of hills, much lower than those on the west border, extends through the middle of the town from north to south. These are slightly more than 100 feet in elevation and they are interrupted by several stream valleys. The lowest altitude is on the east boundary, where a branch of the South Fork crosses the line at an elevation of 35 feet above sea level.

The drainage finds its way into Connecticut River through Park River. Neither of these streams passes through West Hartford, but Park River is formed by the junction of Noyes River, which lies wholly within the town, and Hog River and South Fork, which pass across the northeast and southeast corners, respectively. Trout Brook receives all the drainage from the west half of the town and enters Noyes River about 1 mile north of West Hartford Center. The drainage of the east half is divided among Noyes River, South Fork, and Hog River. Noyes River joins South Fork in the southeast corner of the town.

WATER-BEARING FORMATIONS.

Bedrocks.—The indurated rocks consist of Triassic sandstones and trap sheets. The three trap sheets are separated by beds of sandstone, and dip eastward 10° to 15° at a fairly uniform rate. The trap rocks are more resistant than the sandstones and their outcrops are expressed in the topography by ranges of hills. Talcott Mountains consist of one outcrop of the lowest trap sheet and a repeated outcrop of the middle or main sheet. The upper sheet appears in the range of low hills extending through the middle of the town.

The trap rocks are exposed very generally in the hills in the west part of the town, but the sandstone is almost everywhere covered by drift. It appears in a small exposure in a creek bed just north of Elmwood, and is said to have been quarried at one time in the southwest corner of the town. Both the sandstones and the trap rocks contain numerous cracks which hold small quantities of water, as explained on pages 20 and 22.

Till.—Except for small areas of bare rocks in the ranges of hills, the rock throughout the town is covered with glacial drift, its maximum thickness being about 110 feet. Although the topography here is in general an expression of the bedrock contour and hills usually indicate a thinning of the drift in their vicinity, yet some of the prominent hills consist entirely of drift. A well sunk at the highest

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point on a hill in the northwest corner of the town at an elevation of 400 feet had not passed through the drift on reaching a depth of 85 feet.

Till, which is a mixture of clay, sand, gravel, and bowlders, covers the rock throughout the highest portions of the town, being prevalent at all elevations above 200 feet. The lower part of the till is generally saturated with water and constitutes the source of supply of many private wells.

Stratified drift.—East of the mountains, at elevations of less than about 200 feet above sea level, the surface deposits consist chiefly of lake beds and beach gravels. Between the mountains and the longitude of West Hartford Center the deposits consist chiefly of gravels, and from West Hartford Center eastward to the town line they are chiefly sands. The clay beds, which were formed in the center of the original lake basin, extend up the valley of South Fork into the southeast corner of the town. The gravel beds are generally too thin to be important as sources of ground water, and the clays are too fine grained to give satisfactory yields. The most favorable conditions for ground-water supplies in this town are afforded by the sandy deposits in the central and northeastern parts, where moderate quantities of water can generally be obtained by means of dug or driven wells.

SURFACE-WATER SUPPLIES.

The mountain streams in West Hartford are utilized in the public water supply of the city of Hartford. The streams on the lowlands are too small and sluggish to be useful for power development or public supplies.

All the streams on the lowlands, with the possible exception of Trout Creek, are badly polluted. Hog River, before it reaches Hartford, receives sewage from Bloomfield; South Fork receives sewage from Newington; and Noyes River receives most of the sewage from West Hartford.

GROUND-WATER SUPPLIES.

Dug wells.—Forty-five dug wells, 27 feet in average depth, were examined in West Hartford. Four of them are known to penetrate the rock to depths of 2 to 12 feet; two were said to just reach rock, and the rest end in drift, most of them in stratified drift. None of the wells that enter rock has failed, but one of the two that touch rock fails every summer. Most of the roads in West Hartford follow the tops of ridges and the houses are grouped along the roads. Consequently most wells are sunk in ridges where the water is farther below the surface than at the foot of slopes. Furthermore, there is evidence that in some localities the water table has become lower during the last 25 years, so that wells which formerly passed below the lowest position of the water table are now within the zone of fluctuation.

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Some of these wells could be restored to their original efficiency by cleaning, an operation which seems to have decreased in popularity about as rapidly as the prospects for the extension of the municipal system have increased. Wells, especially those which are dug in sand, need cleaning about once a year; otherwise the infiltration of sand reduces the capacity to such an extent that the wells fail, first in dry seasons, and finally in all except very wet seasons.

Springs.—East of the outcrop of the upper trap sheet the rock troughs are not well defined at the surface and knowledge of the rock topography is unsatisfactory. Springs are common along the streams and many of them are perennial, indicating the presence of continuous supplies near by. A spring about three-eighths of a mile west and a little north of Elmwood, on the Beach farm, yields nearly 20 gallons a minute, or 30,000 gallons a day, of which about 9,000 gallons a day is used. The equipment includes a concrete reservoir and pumping plant. The spring is about one-fourth mile east of the outcrop of the upper trap sheet and near the base of the ridge produced by it. The surrounding slopes appear to be inadequate to afford so large a supply continuously, and it is probable, therefore, that the water delivered by this spring finds its way from the basin west of the ridge through a fissure in the trap. The spring is about 50 feet lower than the bottom of the basin west of the ridge. Other springs in this vicinity yield much less water, fluctuate in harmony with the rainfall, and doubtless get their supplies from the slopes on which they are situated.

Drilled wells.—Drilled wells, affording 2 to 20 gallons a minute, have proved satisfactory for domestic use in West Hartford. Of the 15 wells examined, 13 obtain their water from sandstone; one does not reach rock, but gets its water from a bed of till; and one ends in and draws its supply from trap. These wells are distributed over the entire town; some of them are on the trap hills, some of them in the sandstone troughs, and others in deep drift. Among them every geologic condition in West Hartford is encountered and their general success indicates that water may be obtained anywhere in the town. No very large quantities have been obtained in the traps. The wells which penetrate these rocks generally furnish less than 5 gallons a minute, unless they enter the sandstone, but for ordinary domestic needs 2 gallons a minute is ample, and for other purposes there is no reason to expect drilled wells to be successful. The largest yield yet obtained from trap rocks is 20 gallons a minute, which is by no means a large yield for an industrial or municipal supply. Moreover, this yield is obtained at a depth of 343 feet, which is about as deep as it is ordinarily feasible to drill, since at lower depths water-bearing fissures are less numerous and generally smaller.

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Increase in use of ground water in West Hartford has been at least temporarily arrested by the extension of the Hartford water system, many of the citizens expecting city water to become more generally available and therefore hesitating to invest in well drilling.

SUGGESTED DEVELOPMENTS.

A rock trough lies between the outcrops of the two upper trap sheets and is especially well defined in the south half of the town, where it contains a small stream fed by a number of springs, some of which yield more than 10 gallons a minute (Pl. IX, in pocket). There are no wells in this basin, and its exact depth and water content are not determined. Several smaller troughs lie along the foot of the Talcott Range, all of which contain springs but no wells, as the wells are dug near the roads, which as a rule follow the tops of the ridges in this part of the town. In the largest basins the permanence of brooks and springs and the frequent marshy character of the ground indicate a thorough saturation of the mantle during most of the year, and the conditions indicate that the water table descends only a few feet below the surface even in the driest periods. Wells sunk in these places might be expected to afford sufficient water for domestic needs. At present the habitations are so distributed that the use of wells in this basin for domestic supplies would, as a rule, necessitate conveying the water considerable distances, and involve expenditures closely approaching the cost of drilled wells (p. 39).

In many localities, especially along the foot of the Talcott Range, the water for private use can best be obtained from springs. Springs so situated that the water may be delivered to buildings by gravity usually afford very economical supplies and are to be preferred to wells. Driven wells are recommended in areas of sand and gravel deposits (Pl. IX) because of their high efficiency and low cost, and where more water is required than may be obtained from a single well of this type, a gang of points connected at the surface to a common main may produce the required quantity. Driven wells are not likely to be satisfactory in localities where the water table is maintained at a low level by underground drainage; therefore care should be taken to determine as nearly as practicable the relation of the water table to the surface of the ground at the point where it is proposed to drive the well. The entire zone of fluctuation should lie within the suction limit—about 30 feet—otherwise points can be used only in combination with dug wells so that the pump cylinder may be lowered below the surface. In areas covered by till (Pl. IX) a sanitary dug well (p. 43) is best for moderate domestic use. Supplies from these sources are generally of good quality and adequate for domestic needs. Where the drift is so thin that water is not available throughout the year and where more water is required than may be obtained from dug wells, drilled wells may produce adequate

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quantities (p. 20). But drilled wells also furnish moderate supplies of good water in areas of stratified drift, and they are generally esteemed for their sanitary character.

Under an agreement with the city of Hartford the sections of West Hartford which petition for the privilege may obtain city water. At present families living along the main aqueduct are so supplied and many other parts of the town are reached by branch lines, the eastern half of the town being especially well supplied in this way. (See p. 51.) In sections not reached by the Hartford mains, water is obtained from private wells.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of West Hartford is presented in the following tables:

Dug wells in West Hartford.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
4	Oulaudt	Slope	180	30	28	152			
8		Slope	185	20	16	169		5	
9		Slope	165	14	11	154		0	
10		Plain	150	30	10	140	4		
11		Plain	150	15	10	140	4		
15		Hill	160	22	18	142		40	
16		Hill	164	19	15	149		200	
20	John C. Delaney	Plain	130	16	15.8	114.2			16
22	F. Larenson	Hill	140	30	25	115			
24		Slope	160	40	37	123			
25		Flat	140			95	3	35	
28		Slope	140	30					
29	Henry farm	Slope	150	30	8	142			
31		Hill	125	30					
32	Mansfield	Slope	155	28	25	130	a 5		
33		Slope	155	30	10	145			
35	Hall	Hill	160	16	13	147		10	
36	do	Slope	130	20	16	114			
38	Griswold	Flat	100	12	5.5	94.5			
39	do	Hill	128	26	23	105		0	
40	Woodford	Slope	125	25	18.5	106.5		15	
41		Hill	130	17	14	116		0	
42		Hill	130	20	14	116			
43	M. A. Goodwin	Slope	200	30	26	174		2,400	
46		Valley	180	30	27	153	(a)	10	
47	Finneran	Slope	200	25	13	167	4	95	25
48	C. E. Carlson	Slope	250	45	42.5	207.5	(a)		45
50		Slope	160	12			10.5	320	
51		Slope	185	35	32	153	a.2	20	
52	Flint	Plain	178	40	30	148		0	
53	Mrs. Foot	Plain	170	27				0	20
54		Slope	180	25	22	158	8	20	
55		Slope	280	30			5		
56		Slope	185	30			(a)		
57	Newton	Hill	200	33.5	31.5	168.5	(a)		
60	do	Flat	180	15	12	168	(a)		
62		Slope	110	30			(a)		
63	Beach farm	Hill	160	18	14	146		0	16
65	do	Hill	170	40					
66		Hill	175	21	17.5	157.5			
70	Millard	Hill	180	30	25	155	.3	0	20
71		Slope	185	25			(a)		
73		Hill	145	25	17	128	.05	10	
74		Hill	140	25	20	120			
76	F. Steele	Hill	145	23					12
77	Walbridge	Hill	130	25	20	110	.08	10	
78		Slope	120	20	14	106		560	

a Well goes dry.

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Drilled wells in West Hartford.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.	Section.
		Feet.	*Feet.*	*Galls.*	*Galls.*	*Feet.*			
1	T. Slocum	400	83	5	60	(a)	1910	$181.00	Hardpan.
2	Morgan Braynard	450	265	15	800	107			Hardpan; sandstone.
3	W. B. Miller	195	168	6		44.5	1910	420.00	Gravel; hardpan; red trap.
5	Creamery	190	60	3		34			
12	Schoolhouse	150	52	12		31.8	1910	120.00	Red sandstone.
13	Arthur Allen	165	110	3	600	47	1911	275.00	Sandstone.
14	Judd	155	136		600				
17	Joseph Apter	165	108	4.2	800	50	1911	270.00	Do.
18	James Miller	170	113	10	1,160	70			
19	M. F. Greene	160	240	6	50	65.8	1909	313.50	
24a	St. Mary's Home	130	100	15		25			
26	M. F. Schwertsfeder.	120	118.5	15	120	50	1907	300.00	
37	C. W. Hall	130	50	3		16	1911	125.00	
61	W. J. McCartney	165	67	15		(?)	1904	142.80	Sand, clay, red sandstone, shale.
69	A. G. Wooley	175	175	45	50	10	1900		
75	Frank Steele	145	343	20	80	30	1906	709.00	
79	Coil Pipe Co.	90	197			65	1899	485.00	
80		85	90						

a No rock.

Springs in West Hartford.

Map No.	Owner.	Elevation above sea level.	Yield per minute.	Amount used per day.	Improvements.
		Feet.	*Gallons.*	*Gallons.*	
6		210	10		
7		210	10		1-inch pipe.
21		90	6		
23	F. Larenson	105	4		
27	Henry farm	110	6		
30	Mansfield	115	2		Pumped to barn by wind.
34		120			Windmill.
44	M. A. Goodwin	220	2	0	
45	Bannon	280	2	1,200	Piped.
49	M. F. Schwatlow	250	9		Three-fourths inch pipe.
58		135	10		Tile, 24 inches by 3 feet.
59		175		2,400	
64		130	.5		
67	Beach farm	180		9,000	
68	do	110	20	12,000	Pipe, 2 inches by 8 feet.
72		118	1		

QUALITY OF GROUND WATER.

The analyses in the following table indicate the composition of the water of three wells drilled into the rock at West Hartford. All are hard waters and those represented by analyses 2 and 3 are high in sulphate. According to tests [1] made by the Connecticut State Board of Health in 1898 the water from the well at Elmwood School (depth not given) contains 359 parts of total solids and has a total hardness 225 parts per million, and that from the well at the South Kinder-

[1] Connecticut State Board of Health Rept. for 1898, pp. 292, 295.

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garten (depth not given) contains 166 parts of total solids and has a total hardness of 80 parts per million.

Analyses of water from drilled wells in West Hartford.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2	3
Dissolved solids at 180° C	253	500	630
Total hardness as $CaCO_3$	142	208	210
Silica (SiO_2)	.....	.....	18
Iron (Fe)	.10	1.1	.20
Calcium (Ca)	.....	54	81
Magnesium (Mg)	.....	25	34
Carbonate radicle (CO_3)	.0	6.4	.0
Bicarbonate radicle (HCO_3)	136	156	172
Sulphate radicle (SO_4)	12	220	305
Chlorine (Cl)	14	3.8	3.7

1. Well of H. C. Long; sample collected June 16, 1915.
2. Well of M. F. Schwertsfeder (Pl. IX, No. 26), 118.5 feet deep; sample collected June 24, 1915.
3. Well east of Whitlock Pipe Factory (Pl. IX, No. 80), 90 feet deep; sample collected June 17, 1915.

NEWINGTON.

POPULATION AND INDUSTRIES.

Newington is in the central part of Connecticut in Hartford County. It is reached by the Shore Line division of the New York, New Haven & Hartford Railroad (station Newington), by the Highland division of the same road (stations Newington and Clayton), and by electric railway from Hartford and New Britain. Post offices are maintained at Newington and Newington Junction, and mail is delivered by rural free delivery from New Britain. Newington was taken from Wethersfield and incorporated July 10, 1871. The area of the town is 14 square miles.

The population of Newington in 1910 was 1,689. The population from 1880 to 1910 is shown in the following table:

Population of Newington, 1880 to 1910.

Year.	Population.	Per cent increase.
1880	934	.....
1890	953	2
1900	1,041	9
1910	1,689	62

The principal industry is agriculture.

TOPOGRAPHY.

The surface of Newington is in general flat and stands at an average elevation of about 100 feet. Cedar Mountain extends along the entire east border, reaching elevations of 350 feet in many places. The highest elevation is about 375 feet, near the northeast corner of the town. (See Pl. IX, in pocket.)

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The principal stream in Newington is the South Fork of Park River, which, with its branches, drains practically the entire town. Two small tributaries of Mattabesset River rise in the extreme southeastern corner of the town and drain a small area, most of which is swampy. The general direction of the drainage is northward. All the streams are small, and their average fall is about 10 feet to the mile.

WATER-BEARING FORMATIONS.

Bedrocks.—The indurated rocks in Newington consist of Triassic sandstones and shales, and trap. The trap is exposed in Cedar Mountain. West of Cedar Mountain the bedrocks are sandstones and shales. All the rocks exposed in the central part of the town are sandstone. Shale appears at the surface at several places along the western border. The forces which produced the displacements along the eastern border of the town caused also a general shattering of the rocks throughout the area, and cracks of various widths appear in all the rock exposures and extend from the surface to depths of several hundred feet. Because of these cracks the rocks constitute a reservoir for the storage of underground water and form the source of supply of drilled wells that end in bedrock (p. 20).

Till.—Glacial till, a mixture of clay, sand, gravel, and bowlders covers the rock over the hills along the east border of the town and at many places in the central and western parts of the town. The till was deposited by the retreating ice sheet at the close of the glacial epoch. The most prominent characteristic of the till is the presence of large bowlders, and the distribution of the till is marked by the bowlders scattered over the ground or built into fences along the roads and through the fields. In some places the till is 30 or 40 feet thick, in other places it barely covers the rocks; its average thickness is about 15 feet. Till as a water-bearing formation is discussed on page 15.

Stratified drift.—Deposits of stratified sand and gravel extend along South Fork River and its branches and constitute the most important water-bearing formations in Newington. Many wells have been drilled in the vicinity of Newington Junction and Newington Center to depths ranging from 75 feet to 125 feet before reaching bedrock. These deposits are continuous with similar deposits, partly of lacustrine origin, found in Hartford and East Hartford and the towns northward.

GROUND-WATER SUPPLIES.

In Newington the depth of the water table below the surface of the ground, as determined by the measurement of 50 wells, ranges from 6 feet to 40 feet and averages 18 feet. The least fluctuation occurs in the areas of deep drift in the central portion of the town.

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Fifty-two dug wells, ranging in depth from 8 to 42 feet and averaging 20 feet, were examined in Newington. The yield of wells as determined by measurements of four wells ranges from less than one-fourth gallon to 7 gallons a minute, the average being about 2 gallons. Thirteen of the wells examined are reported to go dry in periods of drought. Four of the wells penetrate rock but obtain their water from the overlying drift. The amount of water used, reported for 25 wells, ranges from 5 to 280 gallons a day and averages 46 gallons.

Thirteen of the drilled wells range in depth from 48 to 232 feet and average 116 feet; eight of these get their water in the bedrock. Their yields ranged from 4 gallons to 40 gallons a minute and averaged 17 gallons. The quantity of water used, as reported for four wells, ranged from 7 gallons to 1,000 gallons a day and averaged 376 gallons.

Data were obtained concerning five springs used by private families. Two of them are said to yield a gallon a minute, and one furnishes 8 gallons a minute. The quantities used from the five springs range from 10 to 2,400 gallons and average 517 gallons daily.

The distribution of the different kinds of drift is indicated on Plate IX, and the types of wells adapted for use in drift are discussed on page 38. The most satisfactory supplies in Newington are obtained from drilled wells. In the sandy area west of Cedar Mountain adequate supplies for domestic use are obtained from drilled wells ending in gravel or coarse sand about 100 feet below the surface. The water in most of these wells will rise within 30 feet of the surface.

PUBLIC WATER SUPPLY.

A cooperative company consisting of 20 members, of which Fred Hubbard is president and Newton Osborne secretary, controls a small system which furnishes water to the members only. Water from a spring on Cedar Mountain is discharged into a small reservoir, from which it is led to Newington Center through a 2-inch main. Each member is entitled to as much water as he desires and no check is kept on the quantity. This company was organized more than 30 years ago and the supply has been ample except during the droughts of the last three summers. The company has acquired a spring situated west of the foot of Cedar Mountain from which, in emergencies, water is pumped by a gasoline engine to the reservoir on the mountain.

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RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Newington is presented in the following tables:

Drilled wells in Newington.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.	Section.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*			
1	.....	.....	.....	.....	.....	.....	.....	.....	
4	Mrs. Geo. P. Brimley	135	100	6	1,000	6	1907	$388.00	Trap.
10	Pimm	80	48	4	.....	29	1899	.....	Hardpan; brown sandstone.
13	Geo. Cooley	.....	124.5	18	.....	.....	1910	248.00	Clay; quicksand; gravel.
14	John F. Bergman	.....	130.5	18	.....	.....	1910	289.00	Quicksand; sand; gravel.
15	James Liquori	100	106	18	.....	.....	1910	240.00	Do.
16	Edward Goodale	80	93	18	.....	.....	1910	198.00	Clay; quicksand; coarse sand.
17	Carl Oscar Danielson.	.....	83	18	.....	.....	1910	169.00	Quicksand; sand; gravel.
18	Newton Osborne	95	159	18	.....	42	1902	318.00	Hardpan; brown sandstone.
19	.....	.....	.....	.....	.....	.....	.....	.....	
21	W. H. Todd	105	100	20	70	100	1899	200.00	Water, top of rock.
22	.....	.....	.....	.....	.....	.....	.....	.....	
30	Mrs. H. M. Robbins.	158	91	8	160	44	1901	180.00	Hardpan; brown sandstone.
39	Frank Rowley	135	73.5	15	.....	31.5	1906	145.00	Red sandstone.
66	Chas. Luce	150	165	25	160	18	1911	368.00	
71	Winter	160	232	40	.....	10	1910	437.00	Brown sandstone 183.5 feet: trap 32 feet.
73	.....	.....	.....	.....	.....	.....	.....	.....	
74	.....	.....	.....	.....	.....	.....	.....	.....	

Springs in Newington.

Map No.	Owner.	Elevation above sea level.	Yield per minute.	Amount used per day.	Improvements.
		Feet.	*Gallons.*	*Gallons.*	
3a	Cutler	140	1	10	Tile 2 by 7 feet.
27	.....	.....	1	10	Reservoir 2 by 6 feet.
37	S. Symolon	100	.....	2,400	
40	Churchill	.....	.....	50	
41	.....	100	8	.....	
55	Carlson	100	.....	60	Barrel reservoir.
62	.....	70	1	60	
64	E. R. Barnard	.....	.....	.....	Pumped by wind.

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Dug wells in Newington.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
2		Slope	118	24	20	98	(a)	30	
3	Cutler	Slope	118	12	8	110	0.05		
5		Slope	115	30	26	89			
6		Plain	90	12.5	10	80			
7		Plain	90	16	12.5	77.5			
8		Plain	90	34	32.5	57.5	(a)	10	
9		Slope	110	16	13	97		15	
11		Plain	80	35	32	48		50	
12	Jeans	Hill	140	18	15	125			
20		Slope	100	17	10	90			
21a		Plain	105	18	15.5	89.5			
23	Calahan	Hill	280	22	19	261	.14		10
24		Hill	280	17.5	14.5	265.5	(a)	20	
25	Blinma	Hill	215	20			(a)	0	14
26	do	Slope	195	8	6	189	.28	25	
28	Macnernay	Plain	135	28.7	27.7	107.3	(a)	25	
29	Miller	Plain	150	33					
31	Mrs. H. N. Robbins.	Plain	140	16	13	127		0	
32	Frank Stetzer	Plain	130	15.5	12	118		280	
33	Blair	Plain	115	10	8	107			
34		Hill	125	26	12	113	(a)		
35	S. Symolon	Flat	115	10	8	107		10	
36		Flat	100	11	7	93			
38	Barrows	Plain	110	17	16	94			
42		Slope	128	14	12	116	(a)	60	
43	Hall	Hill	125	18	13	112			
44		Plain	135	27	25.5	109.5		8	
45		Hill	230	22	18.5	211.5		40	6
46		Hill	240	24	22	218	(a)	5	
47		Slope	245	24	17	228		15	
48		Slope	175	32	27.5	147.5	7		
49	A. F. Pipkin	Slope	160	30	27	133			
50	Chas. Jocklin	Flat	130	12	9	123	(a)		
51	E. R. Barnard	Plain	160	31	27	133		12	
52	do	Flat	146	11	8	138		240	
53	Carl Landell	Hill	170	27	24	146	(a)	160	
54	John Bentson	Flat	150	10	6	144			10
56		Hill	120	12	7	113			
57		Slope	115	15	12	103			
58	John Youhnat	Hill	130	24	22	108		30	
59	August Eckert	Hill	150	42	40	110	(a)	10	
60		Slope	160	13	11.5	148.5		20	
61		Slope	150	19	14.5	135.5		30	
63	E. R. Barnard	Hill	140	39.5	37.5	102.5		0	
65	U. Skomars	Flat	130	24	22	108			
67	Chas. Luce	Slope	155	27	24	131		0	
68		Plain	155	32	23	132			
69	S. B. Bingquist	Hill	160	21	17	143		8	
70	J. A. Johnson	Hill	150	40	30	120		10	
72		Plain	150	30	28	122	(a)	0	
75		Plain	130	19	12	118		10	
76		Slope	95	28	21	74		15	

a Well goes dry.

QUALITY OF GROUND WATER.

Only one ground water from Newington was analyzed, and the results are given in the following table. This is a highly mineralized water, very hard, containing much sulphate. According to a test[1] made by the Connecticut State Board of Health in 1898 the well (depth not given) at Center School yields better water, as its content of total solids is 156 parts and its total hardness 86 parts per million.

[1] Connecticut State Board of Health Rept. for 1898, p. 291.

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Analysis of water from the drilled well of Joseph Belden (No. 81, Pl. IX), collected June 17, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	1,150
Total hardness as $CaCO_3$	580
Silica (SiO_2)	16
Iron (Fe)	Tr.
Calcium (Ca)	187
Magnesium (Mg)	67
Carbonate radicle (CO_3)	Tr.
Bicarbonate radicle (HCO_3)	116
Sulphate radicle (SO_4)	705
Chlorine (Cl)	5.3

WETHERSFIELD.

POPULATION AND INDUSTRIES.

Wethersfield, in the central part of the State in Hartford County, is reached by the Valley branch of the New York, New Haven & Hartford Railroad (stations at Wethersfield and South Wethersfield) and by electric railway from Hartford. There are post offices at Wethersfield and South Wethersfield. The town was settled in 1635 and named in 1637. Its area is 14 square miles.

The population of Wethersfield in 1910 was 3,148. The following table shows the population of the town from 1756 to 1910:

Population of Wethersfield, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	2,483			1840	3,824		1
1774	3,489	40		1850	2,523		34
1782	3,733	7		1860	2,705	7	
1790	3,806	2		1870	2,693		.5
1800	3,992	5		1880	2,173		19
1810	3,961		1	1890	2,271	4	
1820	3,825		3	1900	2,637	16	
1830	3,853	1		1910	3,148	19	

The principal industries are agriculture and the manufacture of tools and mattresses. Shoes are made at the State prison, which is situated here.

TOPOGRAPHY.

The land slopes from the top of Cedar Mountain on the west border eastward to Connecticut River. The highest elevation on the west border is about 325 feet. The land along Connecticut River is less than 20 feet above sea level. Cedar Mountain is formed by an outcrop of Triassic trap brought into position by faulting. The rocks dip eastward and underlie Connecticut River at a depth of about 75 feet. In this part of its course the Connecticut meanders over a broad flood plain, of which about 4 square miles lies within the town of Wethersfield.

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All the drainage in Wethersfield reaches the Connecticut through small brooks. In the south part of the town there are considerable areas of swamp land, but the north half is well drained. Goff Brook, which is the only named stream in the town, rises in a small lake in the southwest corner and enters the Connecticut near Rocky Hill.

WATER-BEARING FORMATIONS.

Bedrocks.—Triassic sandstones and shales underlie all of Wethersfield except the extreme western part, where the trap rock comes to the surface Owing to the great amount of faulting to which this region has been subjected, the rocks are intensely fractured and afford storage for ground water. The fracturing, however, is confined to the upper part of the rock zone, and therefore water can not be obtained at very great depths (p. 20).

Till.—The higher elevations in Wethersfield are covered by till, a glacial deposit consisting of a mixture of clay, sand, gravel, and bowlders. The till is 30 to 40 feet thick in some places, but in many others barely covers the rock surface; its average thickness is about 15 feet. (See Pl. IX, in pocket.)

Stratified drift.—The bedrock in the central part of the town is covered with a thin deposit of stratified drift consisting chiefly of sand. The stratified sands found in Wethersfield are parts of the lake deposits, which are more prominent to the north (p. 48). The occurrence of water in stratified drift is discussed on page 15.

Alluvium.—The surface of the flood plain is alluvium. The character of the deposits underlying the alluvium has not been determined in Wethersfield, but they are doubtless similar to the deposits that occupy the same topographic position in Hartford (p. 48).

GROUND-WATER SUPPLIES.

Fifty dug wells, ranging in depth from 9 to 33 feet and averaging about 20 feet, were examined in Wethersfield. The average depth to water was 16 feet, the extremes being 1 foot and 27 feet. Nearly all of the wells in Wethersfield end in till. Four of those examined penetrate rock and nine have recently failed. The daily consumption of water was reported for 22 wells, the average being 23 gallons. Driven points have been used to a small extent in Wethersfield, generally in combination with dug wells. Two of these wells were examined in which the points were driven to depths of 33 and 45 feet, respectively. From one of these 200 gallons per day is used.

Ten drilled wells range in depth from 40 to 200 feet and average 100 feet, and yield 3 to 60 gallons per minute. The daily consumption reported for eight wells ranged from 6 to 3,200 gallons, excluding one well which is not used, and averaged 475 gallons.

Five springs yielding from one-half gallon to 1 gallon per minute were observed. All were gravity springs and three of them were intermittent.

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PUBLIC WATER SUPPLY.

Wethersfield is supplied with water from the mains of the Hartford waterworks department (see p. 51), the service being metered and controlled by the Wethersfield fire district.

RECORDS OF WELLS AND SPRINGS.

Information concerning various important features of the wells and springs of Wethersfield is presented in the following tables:

Dug wells in Wethersfield.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
2	Mrs. Fols	Slope	145	23	20	125	(a)	0	
5	Standly Viscus	Plain	50	14.5	13	37		3	
8	W. A. Leaver	Slope	60	22	13	47	6		
10		Plain	50	11	10	40			
11		Plain	60	11	8	52	12		
12	R. R. Duncan	Hill	110	30	26	84		40	
14	Goodrich	Plain	85	11	7	78			
20		Plain	215	15	13	202	3	4	
22		Slope	225	23			(a)		
23	Cowles	Hill	223	25	24.5	198.5			22.5
24	Michael Desmond	Slope	205	29	24	81		30	
25	H. E. Wells	Hill	190	28	26	164			
26	C. W. Rhodes	Hill	190	21	20	170	(a)	15	
29	O. A. Raymond	Slope	155	18	13	142		35	
30	George L. Wells	Slope	135	14	12	123		120	
32	Clark	Flat	90	17	15	75		5	
33		Slope	120	16	12	108		15	
35		Hill	116	29	22	94		15	
36	Dix	Hill	150	17	14.5	135.5		5	
39	John A. Isaacson	Slope	110	23	19.5	90.5		40	
40	do	Plain	107	9	6.5	100.5			
41	Antone Gassner	Flat	100	24	17	83		10	
42	Eugene Grover	Flat	100	13	9	91	5	12	
43		Slope	115	23	17	98			
44		Slope	130	22	20	110			
45	Churchill Bros.	Hill	195	21	13	182			
46	C. E. Clark	Hill	210	22	20	190		10	
47	John Olson	Flat	180	24	20	160			
48	J. W. Thomas	Slope	217	25	21	196	(a)		
49	Mrs. Harris	Hill	220	33	27	193		15	
50	K. Kilby	Flat	208	10	8	200		8	
51	H. W. Whaples	Slope	220	33	19	201			
52	Henry Carter	Plain	200	27	26.8	174.2		0	26
54		Hill	200	33			(a)		31
55		Slope	155	30	23	132			
56		Slope	185	23	20	165		6	13
57		Flat	182	15.5	14	168	(a)		
58		Flat	145	11	10	135	(a)	0	
59		Slope	110	24	15.5	194.5			
60		Flat	100	15	14.5	85.5		2	
61	S. E. Wallbeoff	Plain	175	23.5	19	156		75	
62	E. J. Flannagan	Slope	135	23	22.5	112.5	(a)	5	
63	Rev. Waters	Plain	125	14	12.5	112.5			
65	George Baxter	Slope	45	23	10	35			
66		Plain	40	25	23.5	16.5			
67		Plain	45	23	10	35			
68	O. J. Sweeney	Plain	45	22	19	26	(a)		
69		Flat	30	26	1.5	28.5	65		
70	R. G. Fox	Plain	32	15	13	19		40	
71		Plain	35	13.5	11	24			

a Well goes dry.

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Drilled wells in Wethersfield.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.	Section.
		Feet.	*Feet.*	*Galls.*	*Galls.*	*Feet.*			
1	A. Mannel	150	44	10	15	15	1908	$100.00	Sand; hardpan; brown sandstone.
7	Goodrich	170	200	5	30	21	1907	.....	Hardpan; brown sandstone.
9	.....do	170	116	25	0	7	1909	251.00	Hardpan; black shale.
13	R. R. Wolcott	100	60	.....	.....	10	1896	.....	Clay. Water flows.
16	A. G. Hubbard	78	56	60	50	None.	1909	114.00	Brown sandstone.
18	Frank Nowak	73	124	3	8	62	1911	248.00	Clay; gravel.
28	H. W. Wells	195	135	15	15	5	1910	530.00	Trap.
34	F. A. Griswold	117	40	Good.	3,200	.....	1907	.....	
37	John Turner	24	117	.....	6	.....	1905	234.00	
38	J. C. Warner	38	117	.....	.....	.....	1909	.....	

Springs in Wethersfield.

Map No.	Owner.	Elevation above sea level.	Yield per minute.	Improvements.
		Feet.	*Gallons.*	
3	Side of road	135	1	
4	.....	50	1	Keg sunk.
17	.....	76	.....	Hydraulic ram.
19	Mrs. Wallwork	115	1	Keg sunk.
21	.....	.....	½	2 by 2 foot box.
27	.....	175	1	
31	Edward A. Isaacson	95	.....	
53	.....	205	.....	

QUALITY OF GROUND WATER.

An analysis of water from the 200-foot drilled well of Mrs. Goodrich (No. 7, Pl. IX) is given in the accompanying table. It represents a moderately mineralized, fairly hard calcium carbonate or limestone water. According to tests[1] made by the Connecticut State Board of Health the well at the high school (depth not given) yields a water containing 232 parts of total solids and having a total hardness of 120 parts per million, or water similar in composition to that from the Goodrich well, whereas the well water at the second district school contains 140 parts of total solids and has a total hardness of 60 parts per million.

[1] Connecticut State Board of Health Rept. for 1898, pp. 294, 296.

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Analysis of water from the 200-foot drilled well of Mrs. Goodrich (No. 7, Pl. IX), collected June 17, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	337
Total hardness as $CaCO_3$	99
Iron (Fe)	.25
Carbonate radicle (CO_3)	5.8
Bicarbonate radicle (HCO_3)	220
Sulphate radicle (SO_4)	41
Chlorine (Cl)	23

EAST HARTFORD.

POPULATION AND INDUSTRIES.

East Hartford is in the central part of Connecticut, in Hartford County. It is reached by the Highland division of the New York, New Haven & Hartford Railroad (stations at East Hartford and Burnside) and by the Springfield branch of the same road (stations at East Hartford and Burnhams); by electric railways from Hartford, Springfield, Glastonbury, Manchester, South Manchester, and Rockville. Post offices: Burnside, Hockanum, East Hartford, and Silver Lane. East Hartford was separated from Hartford and incorporated in October, 1783. The area of the town is 18 square miles.

The census of 1910 reported the population as 8,138. The population from 1790 to 1910 is shown in the following table:

Population of East Hartford, 1790 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1790	3,016			1860	2,951	18	
1800	3,057	1		1870	3,007	2	
1810	3,240	6		1880	3,500	16	
1820	3,373	4		1890	4,455	27	
1830	2,237		33	1900	6,406	45	
1840	2,389	6		1910	8,138	27	
1850	2,497	4					

The principal industries are agriculture (in which tobacco growing is a specialty) and the manufacture of paper. The repair shops of the Highland division of the New York, New Haven & Hartford Railroad are situated here.

TOPOGRAPHY.

The flood plain of Connecticut River is about half a mile wide. Its east edge is marked by an abrupt rise of 35 feet to the broad terrace that extends eastward about 2 miles to the low hills formed

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by the outcrop of bedrock along the eastern boundary of the town. More than half the town is less than 60 feet above sea level, and not over one-fifth of it exceeds 100 feet. The highest elevation—250 feet—is in Laurel Park, just east of Burnside.

Connecticut River receives all the drainage from East Hartford. Hockanum River, a tributary of the Connecticut, occupies a narrow valley through the middle of the town, and Boyles Brook and Pewterpot Brook drain the remainder. All these streams are small and occupy narrow valleys which have been cut through the terrace.

About one-fourth of the town is under cultivation, and about one-fourth, adjacent to the river, is flood plain; the remaining half is wooded. The terrace lands, constituting about two-thirds of the town, support valuable tobacco fields.

WATER-BEARING FORMATIONS.

Bedrock.—Triassic sandstones come to the surface along the east border of the town. The highest elevation of the rock surface is nearly 250 feet in Laurel Park, just east of Burnside. From this point it slopes downward in all directions but most rapidly westward to about 75 feet below sea level at Connecticut River. The rock is coarse and conglomeratic, is intensely fractured, and owing to texture and structure it contains water which is recoverable by means of drilled wells (p. 20). (See Pl. IX.)

Till.—Unstratified mixtures of clay, sand, gravel, and bowlders deposited by the last retreating glacier cover the bedrock on the hills in Laurel Park. Till is not present at the surface in East Hartford, where the elevation is less than 150 feet, but it forms a comparatively thin layer between the rock surface and the overlying beds of stratified drift throughout the lower parts of the town.

Stratified drift.—The sediments deposited in the Connecticut Valley were in large part assorted and the coarse materials were laid down along the sides and the fine clays in the center of the valley, with materials of medium grade, as sands and fine gravels, in intermediate positions. The zone of gravel deposits barely reaches into East Hartford and sections of gravel are exposed in only a few places in the southeast corner of the town and on the hillsides in Laurel Park. Sand, however, is the predominating surface material. It occurs generally over the terrace lands ranging in thickness from a few inches to 100 feet. The occurrence of water in stratified deposits is discussed on page 15.

Alluvium.—In the flood-plain belt along the river alluvium overlies the stratified drift and in the northwest corner of the town it is about 40 feet thick. It consists principally of fine reddish sand, with a large admixture of mica and some clay. Alluvium extends from the river to the edge of the terrace and follows up the valley of Hockanum River to the wall of the rock valley at Burnside.

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SURFACE-WATER SUPPLIES.

The paper mills at Burnside use water power when it is available, but it is generally necessary to employ steam or electric power during the summer months.

Hockanum River receives sewage from towns situated all along its course and large amounts of waste from textile and paper mills. The smaller streams are much polluted from the residential and rural sections of the town.

GROUND-WATER SUPPLIES.

Thirty-one shallow wells, ranging in depth from 8 to 28 feet, and averaging 16 feet, were measured in East Hartford. The depth from the surface of the ground to the surface of the water in these wells ranges from 2 to 23 feet, and averages 13 feet. The yield was determined approximately in two wells and found to be 3 and 4 gallons a minute, respectively. The amount of water used from 12 of the wells was reported as ranging from 5 to 240 gallons a day, and averaging 78 gallons. Five wells not included in this average are not used at all. Six of the wells examined fail during periods of drought.

Measurements of 30 wells on the terrace indicate that the average depth of the water table is about 13 feet. On the flood plain the average depth to water is less than 5 feet, as is indicated by the presence of moisture at the surface throughout the greater part of the year. The fluctuation of the water table averages about 8 feet on the terrace, but on the flood plain it is about 2 feet, not including the distance to which water rises above the surface of the ground in times of flood.

Eleven drilled wells, ranging in depth from 50 to 525 feet and averaging 173 feet, were examined in East Hartford (p. 71). Seven of the wells penetrate and draw their supplies from the sandstone. The yields of six wells range from 4 to 265 gallons a minute, and average 50 gallons. The quantity of water used was reported for two wells as 159,000 gallons and 60 gallons a day, respectively. The cost of construction, as reported for five wells, ranged from $105 to $247.50, and averaged $180.50.

A spring belonging to W. K. Ackley was reported to yield a gallon a minute. The water is pumped by wind to a 40-foot tank, and the consumption amounts to 240 gallons a day. The altitude of the spring is 22 feet above sea level.

The deep deposits of sand forming the terrace store large quantities of ground water. The general direction of the underflow is westward, and the amount of the fluctuation of the water table increases westward to the edge of the terrace. Conditions here are favorable for the construction and operation of driven wells, and

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wells of this type are recommended to those who desire to obtain water supplies on the terrace. It is probable that supplies sufficient to form important additions to municipal systems are available by this means in this locality.

PUBLIC WATER SUPPLY.

East Hartford is a borough but is governed as a fire district and the water system is owned by the district. The water is obtained in the hills of Glastonbury from brooks that feed two reservoirs having capacities of 1,700,000 gallons and 1,500,000 gallons, respectively, and from these the water is distributed by gravity. The collecting basin comprises about 7 square miles, and is well protected against contamination. This system now supplies most of East Hartford and parts of Glastonbury and South Windsor, or a total population of about 8,000. The daily consumption is about 1,100,000 gallons, or 137 gallons per capita. This supply has been adequate and of excellent quality, but owing to the rapidly growing population and the increasing demand for water the district is prepared to enlarge the supply by the acquisition of other brooks in Glastonbury.

RECORDS OF WELLS.

Information concerning the wells of East Hartford is given in the following table:

Dug wells in East Hartford.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*
1	.....	Plain	45	12	9	36	(a)	0
2	Ruff	Slope	40	11	8	32	.....	0
3	S. E. Roberts	Flat	40	14	12	28	.....	.....
4	C. F. Roberts	Hill	45	10	6.5	38.5	.....	0
5	.....	Slope	100	23	20	80	.....	80
6	Edward Rouff	Flat	115	20	15	100	.....	0
7	Mary S. Hurlburt	Slope	130	18	14	116	3	100
8	Mulchy	Hill	170	25	22	148	4	160
9	Schoolhouse	Hill	180	23	21	159	.....	.....
10	.....	Flat	100	16	14	86	.....	.....
11	R. L. Hoffman	Flat	160	10	8	152	.....	.....
12	U. S. Bailey	Flat	145	10	8	137	.....	5
13	Teat	Flat	140	11	9	131	.....	120
14	.....	Plain	130	15	14	116	(a)	.....
16	Hart	Slope	115	19.5	17	98	(a)	120
17	Lange	Plain	107	17	13	94	.....	.....
19	J. V. Ran	Flat	90	19	16.5	83.5	.....	.....
21	Charles Ott	Hill	100	14	12	88	.....	25
25	.....	Hill	110	13	10.5	99.5	.....	.....
30	.....	Flat	60	12	10	50	.....	15
31	Frederick Hayes	Slope	90	8	7	83	.....	6
32	C. H. Stump	Hill	105	17.5	15	90	.....	50
33	E. A. Williams	Hill	110	28	25	85	.....	.....
34	.....	Plain	65	27	.....	.....	(a)	240
35	Hyram Colburn	Plain	75	12	10	65	.....	20
36	H. L. Cowles	Plain	65	8	6	59	(a)	.....
37	Andy Bidwell	Plain	65	14	13.5	41.5	(a)	.....
38	.....	Plain	.....	.....	.....	.....	.....	.....
39	L. Burnham	Slope	30	16.5	15	15	.....	.....
41	Hamilton Forbes	Slope	80	10	6	74	.....	.....
42	.....	Hill	100	22	21	79	.....	0

[a] Well goes dry.

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Drilled wells in East Hartford.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*		
15	Herbert Kennedy	120	88	8	60	[a] 70	1906	
18	J. W. Crowell	120	150					
20	Mrs. John Hart	110	125	10		25	1900	$245.00
22	Jacob Ott	120	75	Good.		25	1900	127.00
23	Gustave Banzener	125	71	Good.		22	1900	177.50
24	N. Schug	120	82	4		20	1902	247.50
26	Laurel Park	150						
27	Mrs. Levi	65	50			8		[b] 105.00
28	Mrs. John Hansen	65	60	5		10		
29	Eagle Paper Mills Co.	50	280	10			1886	
44	East Hartford Manufacturing Co	38	525				1825	
45	do.[c]	38	395	265	159,000		1855	

[a] Section: Sand; clay; hardpan; brown sandstone.
[b] Drilling only; 18 feet dug.
[c] Well in sandstone; steam pump.

QUALITY OF GROUND WATER.

The 150-foot drilled well of J. W. Crowell (No. 18, Pl. IX) yields a hard, moderately mineralized calcium sulphate water, as the following analysis shows. According to tests[1] made in 1898 by the Connecticut State Board of Health the waters of six school wells (depths not given) in East Hartford range in total solids from 24 to 355 parts, in chlorine from 2 to 72 parts, and in total hardness from 9 to 112 parts per million. These figures illustrate well the variability in composition that may be expected because of local differences in the character of the water-bearing beds.

Analysis of water from the 150-foot drilled well of J. W. Crowell (No. 18, Pl. IX), collected June 16, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	472
Total hardness as $CaCO_3$	236
Iron (Fe)	.30
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	98
Sulphate radicle (SO_4)	218
Chlorine (Cl)	24

MANCHESTER.

POPULATION AND INDUSTRIES.

Manchester is in the central part of the State, in Hartford County. It is reached by the Highland division of the New York, New Haven & Hartford Railroad (stations at Buckland and Manchester) and by electric railway from Hartford and Rockville; the South Manchester Railroad connects Manchester and South Manchester, and the electric railway from Manchester Green connects with all passenger trains at

[1] Connecticut State Board of Health Rept. for 1898, pp. 291-296.

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Manchester; stage from South Windsor to Buckland. Post offices are maintained at Manchester, South Manchester, Buckland, Manchester Green, and Highland Park.

Manchester was separated from East Hartford and incorporated in May, 1823. The area of the town is 21 square miles.

The population of Manchester in 1910 was 13,641. The population from 1830 to 1910 is shown in the following table:

Population of Manchester, 1830–1910.

Year.	Population.	Per cent increase.	Year.	Population.	Per cent increase.
1830	1,576	.....	1880	6,462	53
1840	1,695	8	1890	8,222	27
1850	2,546	50	1900	10,601	29
1860	3,294	29	1910	13,641	29
1870	4,223	28			

The principal industries are agriculture and the manufacture of silk, cotton, and woolen goods, paper, electric appliances, and needles.

TOPOGRAPHY.

Manchester is hilly throughout and practically all the hills are rock. The highest elevation is in the southwest corner of the town, where a group of rocky knobs reaches an elevation of 750 feet above sea level. Two-thirds of the town is more than 200 feet and about half of it is more than 300 feet above sea level. The lowest elevation is 75 feet, where the Hockanum River crosses the east boundary. The terrace lands, which comprise large parts of East Hartford and South Windsor, extend into Manchester and occupy most of the northwest quarter of the town. (See Pl. IX, in pocket.)

About nine-tenths of the drainage of Manchester is received by Hockanum River, which passes through Buckland and Manchester and drains the north half of the town. South Branch, the principal tributary of the Hockanum, passes through South Manchester and drains the south half of the town. The headwaters of Pewterpot Brook and of Salmon Brook reach into the southwest corner of the town and receive a small part of the drainage. The fall of Hockanum River is about 20 feet to the mile, and that of South Branch 60 to 100 feet to the mile east of South Manchester and about 30 feet to the mile from this point west to its junction with the main stream.

WATER-BEARING FORMATIONS.

Bedrocks.—From Manchester Green westward Triassic sandstones comprise the rock floor, but eastward the bedrocks are granite gneisses. The dividing line between these formations is a fault

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extending due north and south through the town. The rock surface is rugged and has a maximum relief of more than 300 feet. Joints or cracks in the rocks are apparent in all exposures, and they afford storage for ground water as explained on page 20.

Till.—On the highlands of Manchester the rock is covered with till or bowlder clay (p. 15), which is in places more than 30 feet thick and is of general occurrence at elevations exceeding 200 feet. It probably occurs also in contact with the rock surface at lower elevations where the surface material is stratified drift. Till varies widely in porosity, and consequently in water-bearing capacity.

Stratified drift.—The occurrence of gravel deposits in a belt nearly 2 miles wide extending from north to south through the middle of Manchester, and of sand covering the rock in the northwest quarter of the town, suggests the conclusion that the stratified drift is deepest beyond the borders of the town. The deposits of sand and gravel are important water bearers, the porosity being high and the storage capacity consequently large. The occurrence of water in glacial drift is discussed on page 15.

SURFACE-WATER SUPPLIES.

Water power has been developed at Buckland, Manchester, and South Manchester, but the supply is not adequate during dry seasons and some of the plants have been abandoned. Mills are frequently obliged to run slack or to employ steam power. Reservoirs for municipal supplies have been located at South Manchester, on Porter Brook near the east border of the town, and at the headwaters of Hop Brook. With few exceptions these reservoirs have furnished adequate supplies.

Large quantities of sewage and wastes from textile mills are discharged into the streams. Wastes from some of the mills in South Manchester are discharged on filter beds which remove a part of the pollution, but much of the polluting matter in solution is carried through and enters the streams. The reservoirs that supply the town are above the sources of pollution and are protected against contamination.

GROUND-WATER SUPPLIES.

Sixty-four wells ranging in depth from 3 to 56 feet and averaging 21 feet were examined in Manchester. The range in depth to water was from 1 foot to 35 feet and the average was 11 feet. Most of these wells end in till and eight of them penetrate rock. They yield in general sufficient water for domestic needs, but 10 wells have recently been dry. The consumption of water, as reported from 28 wells, and not including 9 wells which are not used, ranges from 5 to 120 gallons per day and averages about 23 gallons.

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The depth of 27 drilled wells ranges from 45 to 500 feet and averages about 152 feet. The yield ranges from 3 to 150 gallons a minute. Satisfactory domestic supplies are obtained from drilled wells. Two wells drilled at the Porter reservoir for use in the municipal system were about 200 feet deep and yielded 50 gallons per minute, but they were abandoned because they did not flow and the yield was considered too small to warrant pumping for municipal distribution. Furthermore, when the wells were pumped several important springs which contributed to the reservoir were cut off and it became evident that no additional supply was obtained by pumping these wells.

On the slopes in Manchester are numerous springs, some of which are permanent and furnish sufficient water for domestic supplies. Ten springs were examined ranging in yield from 1.5 to 15 gallons a minute and averaging about 6 gallons. None of these are used on account of their inconvenient situation.

PUBLIC WATER SUPPLIES.

The Manchester Water Co. supplies the village of Manchester at a flat rate from a reservoir near Lydallville, holding between 4,000,000 and 5,000,000 gallons, and the Cheney Bros. Water Co. supplies South Manchester from two reservoirs on Porter Brook near the east border of the town. The reservoirs of the latter company receive drainage from an area of about 1½ square miles and have a total storage capacity of about 161,000,000 gallons. The population supplied is 9,000. The system is partly metered.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells of Manchester is presented in the following tables:

Dug wells in Manchester.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
3a	Z. F. Hills	Plain	120	19	17	103			
4		Plain	150	16	14	136			
7		Hill	175	22	21.8	153.2		0	
8	Gillman	Plain	155	35			(a)	0	32
9		Plain	154	26	22	132		15	13
13	Mrs. E. E. Gillman	Plain	150	27	26	124		30	
17	Slater	Slope	245	12	10	235		12	
18	C. T. Tack	Slope	220	b 7	5	215			
19	M. Doyle	Slope	230	b 3	1	229	5	25	
20	W. McNall	Slope	220	b 9	7	211	5	50	9
21		Plain	200	16	14	186			
22	H. W. Wetherell	Hill	225	36	35	195		10	
23		Hill	190	30	29.8	160.2		0	
24		Hill	183	34					

a Well goes dry. b Well dug in spring.

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Dug wells in Manchester—Continued.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
25	.....	Plain....	185	20	18	167	.....	0	.....
26	.....	Plain....	200	22	20	180	.....	.....	.....
28	.....	Slope....	235	26	25	210	.....	10	.....
29	V. Johnson.....	Plain....	235	14	11	224	.....	.....	.....
30	.....	Flat.....	295	16	15	280	.....	.....	.....
31	Risley.....	(a)	425	21	17	408	.....	60	.....
32	W. L. Fish.....	(a)	420	12	11.9	408.1	.....	0	12
34	L. McKee.....	(a)	430	22	18.5	411.5	.....	.....	.....
35	.....do.....	Flat.....	380	20	18	362	.....	10	.....
36	Joseph Hansen....	Slope....	390	22	19	371	2.5	.....	.....
37	.....	.....	385	8	5	380	.....	.....	.....
42	.....	Plain....	310	22	20	290	(b)	5	.....
43	.....	Plain....	300	13	11.5	288.5	(b)	0	.....
44	.....	Slope....	285	25	23	262	.....	0	.....
45	R. Hastings.....	.....	260	24	22.5	237.5	.....	.....	.....
46	G. Henson.....	Slope....	260	14	13.5	146.5	.....	.....	.....
50	.....	Plain....	225	29	28	197	.....	.....	.....
53	F. Tiechert.....	Plain....	180	27	26.5	153.5	(b)	5	27
54	.....	Plain....	150	28	27.8	122.2	.....	0	.....
56	Cushman.....	Plain....	145	14	13.5	131.5	.....	.....	.....
57	.....	Plain....	145	.....	.....	.....	.....	.....	.....
59	Leritz.....	Plain....	155	25	24	131	.....	20	.....
60	Hill Bros.....	Plain....	130	25	22	108	.....	.....	.....
61	Ralph Noyes.....	Slope....	140	22	19	121	.....	80	.....
62	J. A. Roberts.....	Hill.....	160	c 61	.....	.....	.....	.....	.....
63	F. N. Buckland...	Slope....	170	18	15	155	.....	.....	.....
64	....do.....	Slope....	170	17	.....	.....	(b)	.....	.....
65	Ruddell.....	Plain....	150	14	13	137	(b)	.....	14
66	.....	Plain....	180	29	26	154	.....	.....	.....
70	Schoolhouse.....	Slope....	230	16	11	219	.....	.....	.....
71	.....	Slope....	245	25	18	227	.....	.....	.....
72	.....	Plain....	295	29	25	270	.....	8	.....
73	.....	Slope....	265	17	16	249	.....	.....	.....
74	M. Schildge.....	Slope....	385	24	21.5	363.5	.....	10	.....
76	Fred Browsky.....	Plain....	265	21.5	20	245	.....	25	.....
77	Mrs. Weidman....	Plain....	260	19	16	244	1.5	15	.....
78	Barber.....	Slope....	290	27	24	266	.....	7	.....
79	Wm. Keish.....	Plain....	275	20	17	1"8	.....	.....	.....
81	John Bissel.....	Plain....	290	36	32	258	.....	20	.....
84	E. T. Carrier.....	Hill.....	225	32	31.8	193.2	4	30	.....
87	.....	Hill.....	290	31	29	261	.....	35	.....
88	H. F. Case.....	Slope....	300	32	27	273	.....	0	.....
91	Katherine Calhoun	Slope....	280	17	15.5	264.5	(b)	5	17
92	John Porterfield...	Slope....	280	30	28	252.5	.....	8	.....
93	.....	Slope....	420	17	15.2	404.5	.....	.....	.....
94	Ida Wear.....	Slope....	418	13	11.5	406.5	.....	5	.....
96	D. J. Findley.....	Flat.....	460	15	13	447	.....	8	9
98	.....	Hill c...	750	23	21.5	728.5	.....	.....	.....
99	Joseph Sipper.....	Slope....	700	20	19	681	.....	20	.....
100	J. Barthleim.....	Hill.....	710	15	13	697	.....	5	.....
101	Matuchak.....	Hill d...	740	18	17.2	722.8	(b)	.....	.....

a Located in Bolton.
b Well goes dry.
c Dug 45 feet; point driven 16 feet.
d Well dug in spring.

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Drilled wells in Manchester.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Diameter.	Drilled in year—	Cost.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*	*Inches.*		
3	H. J. Wickham	100	125	5	400	16		1906	$312.50
5	Clint Williams	155	67	Good.		5			74.00
6	do	155	30	Good.		28			60.00
10	Edward Hayes	150	[a] 207	12	450	43			[b] 1,050.00
11	Mrs. Bean	15	102		50				229.00
12	Burr	150	225	Good.				1905	
14	Sumatra Tobacco Co.	150	250						625.00
38	E. S. Ela	400	271					1906	
39	Fred Pitkin	355	200	20	800	4		1901	
40	Wadsworth	315	60			20			
41	W. Pitkin	310	60			20			
47	A. C. Knofla	270	64	3	20				
48	Corbin	255	71	60	15	20		1904	
49	Frish	230	70						
51	Jos. Bier	180	[c] 108	10	12	55		1906	216.00
52	Stone	177	131	5				1908	262.00
55	M. Hayes	118	175			20		1901	
58	Daniels	145	[d] 117						
68	Charles Stimburg	190	[e] 188	Good.		38		1909	264.00
69	Charles Pukosky	200	[e] 105	25	20	16		1908	210.00
80	W. B. Porter	280	[c] 104	Good.	40	54		1910	208.00
82	F. Wittkopski	280	99		25	22		1911	198.00
83	Joseph Hager		150		20			1908	300.00
85	E. T. Carrier	240	[f] 45	4				1899	
86	Renney	280	137						
102	Cheney Bros.		450	[g] 150	([h])	10	8	1903	
103	do	180	500	[i] 150	([j])	50	8	1911	
3B	Mrs. Chapman	120		[k] 3	([j])		6		

[a] Through sandstone and black slate.
[b] Cost of whole system.
[c] Through sandstone.
[d] Drill passed through 11 feet of rock; bottom of well is gravel.
[e] Through red sandstone.
[f] Through sand and clay.
[g] Flowing; mineral content 1,000 grains per gallon.
[h] Total yield.
[i] At depth of 80 feet.
[j] Not used.
[k] Flowing.

Springs in Manchester.

Map No.	Owner.	Elevation above sea level.	Yield per minute.	Improvements.
		Feet.	*Gallons.*	
1	H. J. Wickham	120	8	
2	do	120	8	
15	Sumatra Tobacco Co	160	15	Piped to several houses.
16		160	15	
27		220	2.5	
33	W. L. Fish	[a] 405	3	
75	Frank Schildge	340	Small.	
89	Case Bros		1.5	
90	do		4	
95	D. C. Finley	500	2	Piped to barn.
97		500	1.5	

[a] Spring located in Bolton.

QUALITY OF GROUND WATER.

The four analyses of water from drilled wells in Manchester reported in the following table indicate considerable difference in mineral content, doubtless due to local differences in the character of the water-bearing beds. Two of the wells yield soft water of low mineral content and two yield hard water high in sulphate. All contain little chlorine.

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Analyses of water of drilled wells at Manchester.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2	3	4
Total solids at 180° C.	258	[a] 99	99	455
Total hardness as $CaCO_3$	160	55	26	255
Silica (SiO_2)	.....	12	.....	15
Iron (Fe)	.25	Tr.	.7	.10
Calcium (Ca)	.....	24	.....	.....
Magnesium (Mg)	.....	2	.....	.....
Carbonate radicle (CO_3)	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	94	58	26	74
Sulphate radicle (SO_4)	106	20	5.3	239
Chlorine (Cl)	4.9	2.4	4.2	2.1

[a] Much organic matter.

1. Well of Mrs. Chapman (Pl. IX, No. 3B); sample collected June 16, 1915.
2. Well of H. J. Wickham (Pl. IX, No. 3), 125 feet deep; sample collected June 16, 1915.
3. Well of F. Whitkofski (Pl. IX, No. 82), 99 feet deep; sample collected June 16, 1915.
4. Well of Joseph Hager (Pl. IX, No. 83), 150 feet deep; sample collected June 16, 1915.

SOUTH WINDSOR.

POPULATION AND INDUSTRIES.

South Windsor, in the central part of Connecticut, in Hartford County (Pl. IX), is reached by the Highland division and the Springfield branch of the New York, New Haven & Hartford Railroad (station at South Windsor, East Windsor Hill, Rye Street, and Burnhams), and by electric railway from Hartford and Springfield to South Windsor and East Windsor Hill. The village of Wapping is reached by stage from Buckland station in Manchester. Post offices are maintained at South Windsor, East Windsor Hill, Wapping, Rockville R. D. No. 3, Burnside R. D. No. 1, and Broad Brook R. D. No. 1. South Windsor was incorporated in May, 1845; previous to this date the town was included in East Windsor. The area of the town is 30 square miles.

The population of South Windsor in 1910 was 2,251. The population from 1850 to 1910 is shown in the following table:

Population of South Windsor, 1850 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1850	1,638	.....	.....	1890	1,736	.....	9
1860	1,789	9	.....	1900	2,014	16	.....
1870	1,688	.....	6	1910	2,251	12	.....
1880	1,902	13	.....				

The principal industry is agriculture, especially tobacco growing About one-third of the town is under cultivation, and about 10 square miles is in woodland.

TOPOGRAPHY.

The west half of South Windsor, between the longitude of Wapping and Connecticut River, is a low flood plain, lying in general less than 50 feet above sea level. This flood plain is a little more than a mile

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wide at the southwest corner of the town and gradually narrows to less than a half mile in the northwest corner. A terrace, 3 miles wide, extends eastward from the flood plain. South of Podunk River the surface of this terrace is somewhat hilly, owing to elevations of the rock surface, which reaches a height near Vintons Mills of 275 feet; but from Podunk River north to the latitude of East Windsor Hill the surface is flat and stands at an elevation of about 85 feet. Between Podunk River and Stoughtons Brook the terrace is divided into two benches. The upper one is continuous with the plain in the north end of the town and the lower one, about a half mile wide, stands 50 feet above sea level.

East of the terraced lands the town is hilly. The highest elevation, 390 feet, is in the northwest corner. The average stream gradient in the hilly section is about 60 feet to the mile; in the western half of the town it is about 20 feet to the mile.

The drainage of South Windsor reaches Connecticut River through Podunk River, Stoughtons Brook, and Scantic River. A comparatively small area along the east border is drained by the headwaters of Hockanum River. These streams are all small and the only power developed within the town is at Vinton Mills, where a small sawmill is operated intermittently.

The flood plains along the Connecticut produce hay where the ground is not swampy.

WATER-BEARING FORMATIONS.

Bedrocks.—The bedrocks which come to the surface in many parts of South Windsor are brown sandstones of Triassic age. These rocks underlie the whole of South Windsor but are covered in the eastern part of the town by a heavy mantle of glacial drift. Subsequent to their deposition the sandstones throughout this region were faulted and fractured on a large scale, and as a result the rocks at the present time are cut in every direction by joints which hold ground water (p. 20).

Till.—On the hills along the east border of the town the bedrock is covered with till or hardpan—a mixture of clay, sand, and gravel containing bowlders, some of which are 2 or 3 feet in diameter. Till immediately overlies the rock surface throughout the town, but in the eastern part it is covered by stratified deposits.

Stratified drift.—Thin deposits of gravel are found in South Windsor at elevations between 100 and 200 feet above sea level. Below elevations of 100 feet the rock is covered with sand containing lenses of clay. The occurrence of ground water in glacial deposits is discussed on page 15.

Alluvium.—The flood-plain area marks the distribution of alluvium. This deposit is about one-half mile wide except near the mouth of Scantic River, where it extends eastward into the Scantic River

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valley, beyond the border of the town. The alluvium consists chiefly of sand, but small amounts of clay and organic matter are also present.

GROUND-WATER SUPPLIES.

Sixty-four dug wells, ranging in depth from 8 to 30 feet and averaging about 17 feet, were measured. The depth to water ranges from 7 to 28 feet and averages about 12 feet. Most of these wells are situated in stratified deposits and two of them penetrate rock. Thirteen of the wells have recently been dry. The daily consumption, as reported for 22 wells, ranges from 6 to 4,480 gallons. Driven points are being successfully used in South Windsor. The yield, as determined by measurements of three wells, is about 10 gallons per minute. The depths of seven wells range from 16 to 28 feet and average 22 feet.

The average depth of 13 drilled wells is 123 feet, the extremes being 38 feet and 206 feet. Their yields range from 2 to 30 gallons a minute and average 16 gallons. The consumption as reported for seven wells ranges from 10 to 100 gallons a day.

Seven springs were examined yielding from 1 to 12 gallons a minute and averaging 4 gallons. Four of these are used for domestic supplies, in which the consumption ranges from 60 to 500 gallons a day. All are gravity springs, but they do not respond too readily to changes in the weather. The springs now in use have not been known to fail.

In many places in the eastern part of the town the best supplies both for private and public uses are to be obtained from springs. Springs so situated that the water may be delivered to buildings through pipes by gravity usually afford the most economical supplies and should be preferred to wells. Driven wells are recommended in the areas of stratified drift in the western part of the town (Pl. IX) because of their high efficiency and low cost, and where larger supplies are required than may be obtained from a single well of this type a gang of points connected at the surface to a common main is likely to produce the required amount (p. 40). Infiltration galleries (p. 42) situated at the base of the terrace should afford large supplies, and this method of development, as well as the use of driven wells, should receive consideration in connection with the proposed public supplies.

In areas covered by till (Pl. IX) the best type of well for moderate domestic service is a sanitary dug well (p. 43). Water from these sources is generally good and is adequate for domestic needs. Where the drift is so thin that water is not available throughout the year and where larger supplies are required than may be obtained from dug wells drilled wells may produce adequate quantities of water (p. 38); indeed, drilled wells may yield domestic supplies in any part of the town.

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RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of South Windsor is presented in the following tables:

Dug wells in South Windsor.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*
1	E. A. Sawyer	Hill	75	16	12	63		20
2		Hill	70	20	17.5	52.5		
3		Plain	90	11	7	83	(a)	
5	Edward Risley	Plain	110	10	8.5	101.5	(a)	20
6		Plain	110	10	8	102		
8	John Bryan	Hill	320	28				
9	E. Belknap	Slope	280	15	14	266		
13	Frank Dart	Slope	315	14	12	303	(a)	
14		Plain	280	30	28	252	(a)	
15	Hyram Skinner	Plain	280	18	17	263		0
16	Groves	Hill	285	17	16	269		
17		Slope	210	21	20.5	189.5		
19	Fred A. Pierce	Plain	190	24	23.5	146.5		
20	E. H. Novers	Flat	185	21	18.5	167.5		
21	W. Green	Plain	190	18	17	173		40
22		Plain	192	24	22	170		
24	J. M. Preston	Slope	140	18	16	124		25
25	M. D. Sullivan	Slope	120	15	12	108		
27	Aug. Stubenrough	Slope	160	14	12	148		
31	Frank H. Pierce	Plain	90	11	9.5	80.5	3.7	70
32		Plain	95	11	7	88		15
33	G. W. Hayes	Plain	90	19	18	72		0
36	Arthur M. Hayes	Plain	90	10	8.5	81.5		15
37	W. T. Walker	Plain	90	24.5	23.5	66.5	(a)	6
38	L. P. Brown	Slope	135	28	27	108	(a)	
39	G. S. Thresher	Hill	98	24			(a). 05	
44	R. F. Southergill	Hill	75	16	14	61		15
47	M. J. Meade	Plain	45	14	12	33	4	80
48	Kinary	Plain	40	13	12.5	27.5		0
50		Plain	45	15	14	31		
52		Slope	20	15	13.5	6.5		15
53	Leo Burnham	Plain	40	16	15	25		
56	H. W. Chandler	Plain	70	17	15	55		600
57	James Bradley	Plain	72	15	13	61		
58	J. E. Lathrop	Plain	70	15	12.5	77.5		4,480
59	do	Plain	75	12	11	64	(a)	12
60	Elmore	Plain	65	18	17	48		
61		Plain	73	19	17.5	55.5		
62	Harry Holland	Hill	115	18	17.8	97.2	(a)	
63	J. L. Hayes	Slope	120	b 12	10	110		
64	L. A. Miner	Hill	130	24	21	109	3	10
65		Slope	130	13	12.8	117.2	(a)	
66	G. E. W. Naples	Plain	110	16	14.5	95.2	(a)	10
68		Plain	75	15	11	64		
69		Plain	80	13	12	68		
70	Schoolhouse	Plain	80	14	13.8	66.2		
71	Geo. A. Smith	Plain	80	19	17	63		0
72	do	Plain	80	22	18.5	61.5		
74	Johnson	Plain	115	20	18.5	96.5		
75	do	Plain	115	20	18.5	96.5		
76		Plain	118	11.5	11	107		
77	Burgess	Plain	125	16	14	111		
78	C. P. Clark	Plain	110	19	18	92		
81	Schoolhouse	Slope	140	13	12	128		0
82	Henry Cady	Slope	160	14	11	149		15
83		Slope	150	8	7.8	142.2		0
84		Hill	220	12				0
85	Stroka	Slope	155	13	12.5	142.5	(a)	10
87		Slope	185	18	15.5	169.5		0
92	P. L. Burgess	Slope	260	17	14	246		
93	C. L. Whitmore	Hill	270	19	18.2	251.8		
96	C. T. Tack	Hill	268	14	13	255		15
97	K. Lifkolte	Slope	200	14	8	192		20
98	Frank Rogers	Hill	335	c 22	19.5	315.5		10

a Well goes dry. b Depth to rock, 12 feet. c Depth to rock, 16 feet.

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Driven wells in South Windsor.

Map No.	Owner.	Elevation above sea level.	Depth.	Depth to water.	Yield per minute.
		Feet.	*Feet.*	*Feet.*	*Gallons.*
34	G. W. Hayes		28	16	[a] 10
35	do		28	16	[a] 10
40					
41					
42					
43					
45					
46	E. D. Farnum	50	27		10
49		45	18		Good.
51		45	20		Good.
54	Mrs. Ray		16		[b] Good.
55	Geo. H. Andrews	65	18		Good.

[a] 30 to 40 gallons used per day. [b] 40 gallons used per day.

Drilled wells in South Windsor.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*		
11	J. S. Brown	315	137		100			
12	Frank Dart	335	162	13	60	47	1911	
18	J. W. Graham	220	[a] 161	30	85	3.5		
23	Nickols	135			30			
28	Johnson	150	[b] 118	5	84			
67	E. E. Clark	130			40		1908	
79	L. J. Grant	120	160	20			1911	
80	Wapping M. E. parsonage	120	110			68	1911	
86	C. Grant	170	100				1908	
88	Wm. Clark	170	[c] 96	15		30	1907	$240.00
89	Will Felt	215	110	2			1901	
90	Simler	130	102	25				
94	P. Jennings	250	100	15	10		1909	
95	Mrs. W. C. Thompson	200	38	20		8	1899	50.00
99	Levi Felt	350	206		0			

[a] Red sandstone. [b] 30 feet of sand, then hardpan to rock. [c] Sand, gravel, and rock.

Springs in South Windsor.

Map No.	Owner.	Elevation above sea level.	Yield per minute.	Amount used per day.	Improvements.
		Feet.	*Gallons.*	*Gallons.*	
4	Michael McGrath	95	1.5	70	Hydraulic ram.
7	O'Connor & Havlin tobacco farm	138	10	100	Wind and gasoline engine.
10	Budy	315	1.5		Wind. Piped to house and barn.
26		90	2.5		
29		130	1		
30		100		60	Hydraulic ram.
73	Geo. A. Smith	100	2		Do.
91	Wapping creamery	200	12	500	

EAST WINDSOR.

POPULATION AND INDUSTRIES.

East Windsor (Pl. IX) is in central Connecticut in Hartford County. It is reached by the Highland division and the Springfield branch of the New York, New Haven & Hartford Railroad, with stations at Osborn, Broad Brook, and Melrose, and by the main line of the same

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road, with station at Warehouse Point; by electric railways from Hartford, Springfield, and Rockville. Post offices: East Windsor, Windsorville, Melrose, Broad Brook, and Warehouse Point.

East Windsor was taken from Windsor and incorporated in May, 1768. The area of the town is 27 square miles. The population in 1910 was 3,362.

The following table shows the population of the town from 1774 to 1910:

Population of East Windsor, 1774 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1774	2,999	.....	.....	1850	2,633	.....	[a] 27
1782	3,237	8	.....	1860	2,580	.....	2
1790	2,600	.....	20	1870	2,882	12	.....
1800	2,766	6	.....	1880	3,019	4	.....
1810	3,081	11	.....	1890	2,890	.....	4
1820	3,400	10	.....	1900	3,158	9	.....
1830	3,536	4	.....	1910	3,362	6	.....
1840	3,600	2	.....				

[a] South Windsor was set off from East Windsor in 1845.

About one-fourth of East Windsor is wooded and two-thirds of the town is under cultivation. Approximately 1,200 persons are engaged in agriculture. The manufacture of woolen and silk goods also forms an important industry. Rye gin is made on a large scale at Warehouse Point.

Water power is used at Broad Brook and at Windsorville, both of which are situated on tributaries of Scantic River.

TOPOGRAPHY.

Along the east border of East Windsor irregularities in rock surface produce hills ranging in height from 200 to 300 feet. The area characterized by this topography is about a mile wide and extends along the entire east border. Between this area and Connecticut River is a plain which is about 100 feet in general elevation and which is dissected nearly to sea level by Scantic River and its tributaries. The valleys of these streams are narrow and the areas between them are poorly drained. This plain is probably a part of the bed of a lake which formerly occupied much of the Connecticut Valley north of Rocky Hill.

The principal stream, Scantic River, enters the town about a mile west of Melrose and flows diagonally across to the southwest corner, where it joins the Connecticut. Its principal tributaries are Broad Brook and Ketch Brook, which drain the east half of the town. The west half is drained by Priors Creek and several short brooks which empty into the Connecticut. (See Pl. IX, in pocket.)

WATER-BEARING FORMATIONS.

Bedrocks.—Bedrocks—all Triassic sandstones—appear at the surface in the hills just east of Warehouse Point, at numerous places

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along Scantic River and its tributaries, and in the hills along the east border of the town. Numerous joints, many of which are water bearing, traverse the rock in all directions and constitute the source of the ground water obtained from rock borings, as explained on page 23.

Till.—The bedrock in the eastern part of the town is covered with till—a glacial deposit consisting of mixtures of bowlders, gravel, and sand, with small amounts of clay—which ranges in thickness from a mere film on the hilltops to 25 or 30 feet in the valleys. Wells drilled through the stratified drift in the eastern part of the town have all encountered till immediately overlying the bedrock. It is believed, therefore, that till lies between the stratified drift and the rock surface. The occurrence of water in till is discussed on page 15.

Stratified drift.—The till-covered areas are surrounded by stratified deposits consisting of coarse sand and gravel, and gravel deposits are found along the east border of East Windsor overlying the till at elevations of less than 225 feet. On the plains in the eastern part of the town the surface material is principally sand containing lenses of clay and ranging in depth from a few feet to about 100 feet (p. 15).

Alluvium.—Immediately along Connecticut River the surface material is alluvium, but the deposit is only a few yards wide. The alluvium also extends up the valley of Scantic River from its mouth through East Windsor and Enfield.

GROUND-WATER SUPPLIES.

The depth of dug wells in East Windsor, as determined by measurement of 31 wells, ranges from 10 to 65 feet and averages 17 feet. Depth to water ranges from 2 to 58 feet and averages 14 feet. Most of these wells end in stratified deposits and yield adequate supplies. Only two wells have recently been dry. The daily consumption of water reported for 15 wells ranges from 15 to 100 gallons. Four of the wells examined are not used.

Twenty-seven drilled wells, ranging in depth from 86 to 386 feet and averaging about 166 feet, and yielding 2.5 to 85 gallons a minute, were examined. Twenty-six of these wells penetrate rock. The daily consumption, as reported for 14 wells, ranged from 10 to 25,000 gallons.

Small springs are common along the streams but are generally intermittent and are so situated as to be unimportant as sources of water for domestic use. A few permanent springs on the slopes in the central and western part of the town are capable of development. One of these yields about 6 gallons per minute and is subject to slight variation throughout the year.

In the western part of the town, where the surface deposits consist largely of sand, one of the most suitable types of wells is the driven well described on page 40. Wells of this kind are especially desirable

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for tobacco irrigation, as they may be sunk at convenient spots in the fields and may be constructed in a few hours and at a very moderate cost. Such wells would be very useful in fields to which water must now be hauled from distant wells.

PUBLIC WATER SUPPLY.

A private company supplies water to Broad Brook, principally for fire protection but to some extent for domestic use. One reservoir, about 5,000,000 gallons in capacity, is situated about 1½ miles southeast of the village. The revenue is collected at a flat rate. A reservoir might be constructed 2 miles east of the city near the head of the tributary that joins Broad Brook just north of the city, but the quantity of water carried by this stream should be determined before any development is undertaken. The available head is about 75 feet and the catchment area is about 3 square miles. Wells might also be sunk by driving perforated well casings into the stratified deposits near Scantic River to a depth of about 100 feet or to bedrock.

RECORDS OF WELLS.

The available information relating to the wells in East Windsor is set forth in the following tables:

Dug wells in East Windsor.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
1	W. A. Lord	Hill	130	18	17	113		0	18
2	John Winker	Plain	100	18	13	87			
4	Martin Cuscovitch	Plain	115	12	8	107		20	
5	M. Bagg	Plain	120	10	6	114		20	
6	C. C. Parker	Plain	110	14	9	101		25	
7	Fred Schlichting	Plain	115	15					
10		Plain	145	15	14	131			
12	Wm. Hill	Plain	120	18	15.5	104.5	5	35	
13	Richard Carroll	Hill	196	65	58	138			
23	Herman Krah	Hill	130						
24	I. H. Stiles	Slope	130	13	12	118			
25	H. A. Hunt	Plain	105	13	10	95		20	
26	Barton Wells	Plain	100	11	9	91			
28	Thomas Porter	Plain	107	14	12	95			
29		Plain	100	13	7	93		20	
30	Allen	Flat	100	14	2	98			
31		Plain	107	18	16.5	90.5			
32	E. P. Carter	Hill	130	14	11	129		30	
34		Plain	55	12	9	46			
35	J. O. Walker	Slope	60	18	16.5	43.5	(a)	20	
36		Plain	65	15	13.5	41.5		40	
37		Hill	80	12	10.5	69.5		0	
38	W. P. Bissel	Hill	106	25	14	92		20	
39		Hill	100	12	6	94			
40	Town farm	Slope	110	11	8	102		100	
41	J. F. Strong	Hill	105	27	25.5	79.5	2.5	15	
45	H. J. Allen	Hill	140	21	13	127		25	
47	W. H. Tallcott	Hill	80	12	10	70	(a)	15	
48	John Sheridan	Slope	95	25	23.5	71.5		0	
56		Flat	90	17	15	75			
58	Barnard	Plain	85	22	19	66			
59	H. M. Doane	Slope	220	22	18.5	201.5	10	30	22

a Well goes dry.

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Drilled wells in East Windsor.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.	Section.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*			
3	H. W. Allen	105	222	30	50	120	1906	$444.00	Sand; clay; brown sandstone.
8	E. M. Granger	150	270	22	60	100	1900	540.00	Sand; clay; hardpan.
9	A. H. Grant	150	100	15	75	50	1902	.....	
11	Francis Dowdy Distilling Co.	125	310	85	.....	40	1900	620.00	Sand; gravel; hardpan.
14	Michael Sullivan	230	150	75	100	60	1905	300.00	Sand; hardpan.
15	Ertel	148	109	40	.....	56	1910	218.00	Do.
16	F. A. Curtis	150	102	40	25	60	1907	204.00	Do.
17	Frank Dowd	150	100	48	.....	73	1911	200.00	Do.
18	Wm. Morris	178	138	40	.....	86	1910	276.00	Do.
19	R. C. Lasbury	180	257	34	80	135	1910	514.00	Do.
20	.....do	175	109	12	.....	45	1911	218.00	Sand; quicksand; bowlders.
21	J. P. Norton	180	86	32	.....	70	1900	360.00	Sand; quicksand; hardpan.
22	Miskill	170	154	18	.....	48	1911	340.00	Sand; hardpan.
27	Robert Bartlett	200	386	2.5	40	21	1910	772.00	Sand; clay; hardpan.
33	E. Newberry	145	143	5	60	15	1909	321.75	
42	Farnham	145	298	50	25,000	168	1910	596.00	Sand; hardpan.
43	Fred Ellsworth	145	160	Small.	.....	.....	1885	.....	
44	Albert Ellsworth	135	246	30	1,285	166	1911	492.00	Sand; clay; hardpan.
49	John Sheridan	200	102	6	20	10	1910	204.00	Sand; hardpan.
50	Joseph Titus	200	155	10	10	23	1911	310.00	Do.
51	John Leentie	200	210	16	.....	80	1911	420.00	Sand; clay; hardpan.
52	Michael Dunn	195	90	6	.....	38	1903	190.00	Sand; hardpan.
53	Wm. Stasowitz	200	87	25	.....	23	1910	174.00	Do.
54	Andrew Hoffman	210	86	10	30	40	1903	172.00	Do.
55	Jacob Gilson	215	114	3	.....	32	1911	228.00	Do.
57	Geo. Barnard	220	211	10.5	30	9	1911	422.00	Do.
60	Howard Hamilton	225	86	60	.....	76	1910	172.00	Do.

QUALITY OF GROUND WATER.

The deeper of the two wells analyses of whose waters are given in the accompanying table yields a highly mineralized sulphate water. Data at other places in Connecticut, however, do not corroborate the conclusion that the shallower rock water is uniformly better than the deeper, and possibly the results of analyses of other rock waters in East Windsor would indicate opposite conditions.

Analyses of water of drilled wells in East Windsor.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2
Total solids at 180° C.	202	849
Total hardness as $CaCO_3$	142	133
Silica (SiO_2)	.....	10
Iron (Fe)	Tr.	.15
Calcium (Ca)	.....	54
Magnesium (Mg)	.....	1.5
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	182	86
Sulphate radicle (SO_4)	11	344
Chlorine (Cl)	6.9	29

1. Well of E. Newberry (Pl. IX, No. 33), 143 feet deep; sample collected June 18, 1915.
2. Well of Robert Bartlett (Pl. IX, No. 27), 386 feet deep; sample collected June 18, 1915.

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WINDSOR.

POPULATION AND INDUSTRIES.

Windsor, in the central part of the State, in Hartford County, is reached by the Hartford division of the New York, New Haven & Hartford Railroad, with station at Windsor and flag stations at Wilsons and Haydens; by electric railway from Hartford to Rainbow and from Springfield. Post offices are maintained at Windsor, Poquonock, Rainbow, and Wilson.

Windsor was settled in 1635 and named in 1637. The area of the town is 31 square miles.

The population of the town in 1910 was 4,178. The following table shows the status of population from 1756 to 1910:

Population of Windsor, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	4,220			1840	2,283		29
1774	2,125		[a] 49	1850	3,294	44	
1782	2,382	12		1860	3,865	14	
1790	2,714	14		1870	2,783		28
1800	2,773	2		1880	3,068	10	
1810	2,868	3		1890	2,954		3
1820	3,008	5		1900	3,614	22	
1830	3,220	7		1910	4,178	16	

[a] East Windsor was set off from Windsor in 1768.

About one-third of Windsor is under cultivation. The principal industry is agriculture, the main crop grown being tobacco.

Nearly one-half of the area included in the town is wooded.

Water power is developed at Rainbow and Poquonock, both of which are situated on Farmington River.

TOPOGRAPHY.

Windsor lies entirely within the area once leveled by glacial lake deposits, and the present topography has been produced by the dissection of the lake plain. The highest elevation in the town—270 feet above sea level—is on the boundary near the northwest corner. At no other place does the elevation exceed 220 feet. The flood plain of Connecticut River, which is less than 20 feet above sea level, is about a mile wide near the mouth of Farmington River, but narrows both northward and southward from this locality, covering an area of about 3 square miles. The average elevation of the town is about 150 feet, and about four-fifths of its area lies between 100 and 200 feet above sea level. (See Pl. IX, in pocket.)

Farmington River has cut a narrow, steep-walled valley across the town and its tributaries are short and straight, leaving considerable areas between them without adequate drainage. Small lakes and ponds are found on these areas after rains, and in two or three shallow

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basins between Poquonock and North Bloomfield water stands throughout the year. Previous to the ice invasion Farmington River probably flowed due south from Farmington through Southington and Cheshire to the sound at New Haven. Its valley was dammed by glacial deposits at Southington, and the stream was deflected northward along the Talcott Mountains to Tariffville, where it found a passage through the range and then meandered across the lake plain in Windsor to Connecticut River. The total fall of the river within the limits of Windsor is 100 feet.

WATER-BEARING FORMATIONS.

Bedrock.—Triassic sandstones and shales underlie the town and are exposed at several places along Farmington River and in some of the gullies tributary to it. Trap rocks do not outcrop in Windsor but appear at the surface near the town line in East Granby and, overlain by sandstone, extend eastward through Windsor. Both the sandstones and the trap have been intensely fractured. Numerous cracks, cutting the rocks in all directions, dipping at all angles, and ranging from microscopic size to widths of several inches, afford storage for ground water. The occurrence of water under these conditions is discussed on page 20.

Till.—The till consists of unstratified glacial débris deposited by the melting ice. The material is principally sand, but contains a small amount of clay and a large amount of gravel and bowlders. Till covers the rock in the north part of the town and in patches along Farmington River and southward to Wilson. The thickness of the till is variable, owing to the unevenness of the rock surface. In the deepest portions it is about 50 feet thick, but the average thickness is probably not more than 20 feet.

Stratified drift.—Stratified drift occurs quite generally in Windsor. It consists chiefly of sand in the north parts of the town, but contains beds of clay in the extreme southern part. These deposits correspond in geologic position to the terraced deposits on the east side of Connecticut River in South Windsor (p. 15).

GROUND-WATER SUPPLIES.

Twenty-four shallow wells, ranging in depth from 8 to 36 feet and averaging 16 feet, were examined. One of these, a driven point, 10 feet deep and 1¾ inches in diameter, yielded a good supply of water; the others were dug wells of the usual diameter, about 2½ feet. The approximate yield of three of the wells was determined as 3.5 gallons, 4 gallons, and 8 gallons a minute, respectively. One well which yielded a very small quantity at the time it was examined

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was said to fail in dry weather. The quantity of water used was reported for 12 wells, the range being 15 to 60 gallons and the average 26 gallons a day. All the wells examined end in the drift.

The depth of drilled wells in Windsor, as estimated by examination of 10 wells, 7 of which end in bedrock, ranges from 44 to 337 feet and averages 147 feet. The yields were reported for 5 wells and range from 4 to 35 gallons, averaging 15 gallons a minute. The consumption, as determined for 6 wells, ranges from 20 to 45 gallons a day and averages 35 gallons.

Measurements of 23 wells indicate that the water table lies 3 to 34 feet below the surface of the ground in Windsor, the average depth being 12 feet. Owing to the incomplete drainage, however, water stands at the surface of the ground at many places between the stream courses during the greater part of the year, and in and near such places adequate water supplies are readily obtainable. The wide distribution of sand deposits in Windsor favors development by means of driven wells, which would meet a special need for the cultivation of tobacco, the growing of which is confined to the sand plains.

RECORDS OF WELLS AND SPRINGS.

Information concerning the wells and springs examined in Windsor is presented in the following tables:

Dug wells in Windsor.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*
4	.....	Plain	120	13	10	110	.....	.....
5	Scheely	Plain	90	18	13	77	8	15
6	.....	Valley	100	10	7	93	.....	.....
7	W. H. Dickinson	Slope	120	20	16	104	.....	20
9	L. J. Daniels	Slope	92	13	9	83	(a)	.....
11	.....	Plain	76	9	6	70	.....	.....
12	Henry M. Scott	Plain	130	12	9	121	.....	30
13	.....	Slope	140	27	13	127	.....	20
14	E. Delebrand	Plain	145	15	12	133	.....	25
15	.....	Slope	125	8	3	122	.....	.....
17	Wm. Cook	Plain	130	9	7.5	122.5	4	20
18	W. A. Graham	Plain	110	8	5.5	104.5	.....	18
19	do	Plain	110	8.5	6.5	103.5	.....	.....
20	Joe Twalcunis	Slope	140	15	14	126	.....	.....
21	Mrs. Rood	Plain	90	17	15	75	.....	15
23	John King	Plain	100	20	17	83	.....	40
24	Hensen	Plain	100	13	9	91	.....	20
25	.....	Plain	104	9	6	98	.....	.....
28	Mrs. Moore	Slope	90	36	33.5	.....	.....	0
31	.....	Slope	83	32	31.8	51.2	.....	.....
34	D. W. Bayley	Slope	35	10	7	28	.....	60
35	A. Christensen	Flat	30	18	17	13	.....	0
36	Seth Marsh	Hill	55	20	14	41	3.5	30

a Well goes dry.

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Drilled wells in Windsor.

Map No.	Owner	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year.	Cost.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*		
1	Jacob Lang	140	167	8	45	80	1907	.....
2	Clark Bros	140	62.5	Good.	.....	.....	1909	.....
3	W. L. Wolfe	140	219	.....	.....	.....	.....	.....
10	J. H. Smith	100	[a] 167	Good.	.....	70	1906	$334
22	John C. King	100	[a] 337	4	.....	97	1910	.....
26	Albert Arnurius	85	[a] 82	35	25	31.5	1908	.....
27	Mrs. O. B. Moore	85	[a] 111	25	25	31	1900	.....
29	Mrs. Henry Fox	80	[a] 143	5	25	37	1909	.....
30	F. V. Mills	85	135	.....	40	35	1906	.....
32	Bert Philips	80	44	Good.	20	.....	1898	.....

[a] Sandstone.

Springs in Windsor.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.
		Feet.	*Feet.*	*Gallons.*
8	Merwin	140	.....	3
33	N. Christenson	25	.....	1.5

QUALITY OF GROUND WATER.

The four analyses of water from drilled wells represent supplies moderate in mineral content but rather hard. They are all of the calcium carbonate type and low in sulphate and chlorine.

Analyses of water from drilled wells in Windsor.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2	3	4
Total solids at 180° C.	358	172	218	195
Total hardness as $CaCO_3$	190	84	155	112
Iron (Fe)	.10	.30	Tr.	Tr.
Carbonate radicle (CO_3)	Tr.	2.8	4.8	Tr.
Bicarbonate radicle (HCO_3)	273	137	240	202
Sulphate (SO_4)	24	27	11	4.3
Chlorine (Cl)	32	4.4	2.1	6.4

1. Well of F. V. Mills (Pl. IX, No. 30), 135 feet deep; sample collected June 17, 1915.
2. Well of J. H. Smith (Pl. IX, No. 10), 167 feet deep; sample collected June 18, 1915.
3. Well of Albert Arnurius (Pl. IX, No. 26), 82 feet deep; sample collected June 17, 1915.
4. Well of Mrs. O. B. Moore (Pl. IX, No. 27), 111 feet deep; sample collected June 17, 1915.

BLOOMFIELD.

POPULATION AND INDUSTRIES.

Bloomfield, situated in the central part of Connecticut, in Hartford County, is reached by the Central New England Railway (stations at Cottage Grove, Bloomfield, and North Bloomfield), and by electric railway from Hartford. The post office is Bloomfield. Rural free delivery serves outlying parts of the town.

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The town was incorporated in May, 1835. It has an area of 28 square miles.

The population of Bloomfield in 1910 was 1,821. The population from 1840 to 1910 is shown in the following table:

Population of Bloomfield, 1840–1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1840	986	.....	.....	1880	1,346	.....	9
1850	1,412	43	.....	1890	1,308	.....	3
1860	1,401	.....	0.8	1900	1,513	15	.....
1870	1,473	5	.....	1910	1,821	20	.....

The principal industries in Bloomfield are dairying and agriculture. Tobacco is grown on a large scale.

TOPOGRAPHY.

The west border of Bloomfield lies along the crest of the Talcott Mountain range. The elevations along this border are 500 to 800 feet above sea level. The land slopes steeply eastward and the level of the plains is reached within a distance of about 2 miles. The eastern two-thirds of the town stands about 150 feet above sea level and constitutes part of the lake plains which extend along both sides of Connecticut River above Hartford.

Hog River is formed by the confluence of Wash Brook and other smaller brooks near Cottage Grove. Its headwaters receive the drainage from all parts of the town. The average fall of Wash Brook is about 6 feet to the mile. A very small amount of drainage passes into Mill Brook which crosses the extreme northeast corner. The eastern part of the town is very flat and the streams have not established a complete drainage system. There remain therefore many undrained or poorly drained areas which are swampy throughout the greater part of the year. (See Pl. IX, in pocket.)

WATER-BEARING FORMATIONS.

Bedrocks.—The indurated rocks in Bloomfield consist of Triassic sandstones, shales, and traps. The outcrops of the three trap sheets produced the Talcott Mountains. Sandstones overlie the traps in the eastern part of the town but are covered by drift. A characteristic feature of the bedrocks is the extensive fracturing, as a result of which they constitute an important reservoir for the storage of water (p. 40).

Till.—Unstratified deposits of sand, gravel, bowlders, and small quantities of clay cover the rock on the hills along the west border of the town. These deposits vary in thickness according to the

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topography. On hilltops bedrock is exposed or barely covered, but on slopes the mantle is in some places 50 feet thick. The till extends eastward to the base of the hills. Its distribution is indicated by bowlder-strewn fields and stone fences and its thinness in general is indicated by the numerous outcrops of bedrocks. The quantity of water in the till is variable, depending on the rainfall, porosity of the material, and topographic position (p. 15).

Stratified drift.—The plains in the eastern part of the town are part of the bed of an ancient lake which once occupied a large area in the Connecticut Valley north of Rocky Hill. The deposits here consist principally of sand with lenses of gravel along the west margin. The sand deposits in the central and eastern parts of the town range in thickness from 10 to 125 feet. They contain fairly large quantities of water and are porous enough to yield adequate supplies for domestic use and the irrigation of tobacco fields (p. 15).

GROUND-WATER SUPPLIES.

In Bloomfield the depth of the water table below the surface of the ground, as determined by measurements of 44 wells, ranges from 5 to 30 feet and averages 13 feet. The fluctuation is greatest in the hills along the west border of the town, where extreme variations are common, owing to the rapid underflow on the steep slopes. In the east half of the town the stratified deposits are thick and the underflow is not rapid. At many places water stands on the surface throughout the year. In this section the fluctuation is very slight.

Forty-six dug and driven wells examined in Bloomfield range in depth from 7 to 43 feet and average 18 feet. Three of these are reported to pass entirely through the drift and to penetrate rock. The quantity of water used, as reported for 20 wells, ranges from 2 to 50 gallons a day and averages about 20 gallons.

Six of the driven wells in the northeast corner of the town range in depth from 10 to 25 feet, the average being 16 feet, and the points commonly used are 3 feet long and 1¾ inches in diameter. These wells obtain water in the stratified deposits and furnish supplies for domestic needs and for tobacco irrigation.

Thirteen of the drilled wells range in depth from 28 to 190 feet and average 98 feet. Eight of these wells draw water from bedrock. Ten wells were reported to yield 5 to 20 gallons a minute, the average being 13 gallons. The quantity of water used, as reported for four wells, ranged from 5 to 75 gallons a day, and the daily average per well was about 50 gallons. The wells cost $100 to $300; the average for five wells was $226.

Six springs examined in Bloomfield yielded one-half gallon to 11 gallons a minute and averaged 4½ gallons. Four of these furnish

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private supplies, the quantities used ranging from 20 to 400 gallons a day and averaging 153 gallons.

The small gravity springs found along the slopes of Talcott Mountains are both convenient and economical for use where arrangements can be made to deliver their water to houses and barns. In the hilly sections of the town, where springs are not available, suitable supplies can probably be obtained from dug wells equipped as described on page 43.

On the sand plains in the eastern part of the town driven wells are recommended for domestic use and for tobacco irrigation. In the areas where unstratified drift constitutes the rock cover driven wells can not be used to advantage, but dug wells will generally furnish insufficient water for domestic needs.

Drilled wells are not dependent on the character of the rock or drift and may be expected to furnish moderate quantities of water anywhere in the town.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Bloomfield is presented in the following tables:

Drilled wells in Bloomfield.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—	Cost.
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*		
20	A. C. Case	210	60	6	0	7	.....	.....
21	.....do	215	40	0	0	7	.....	.....
22	.....do	218	[a] 96	14	5	6	.....	.....
44	Henry Keeny	130	147	.....	60	.....	1899	.....
46	Alfred Marshall	135	136	.....	50	.....	1899	.....
50	Post office	125	[b] 40	10	.....	.....	1911	$100
51	W. L. Burnham	125	28	20	75	28	1897	.....
52	Mrs. G. K. Marvin	135	85	5	.....	75	1911	.....
53	H. C. Cadwell	125	138	20	.....	69	1911	.....
54	Jas. Francis	135	[c] 190	8	.....	82	1909	380
55	Hutchinson	145	[c] 135	12	.....	58	.....	220
61	Carrol Davis	160	.....	.....	.....	.....	.....	.....
72	Edw. McKune	110	[d] 110	20	.....	.....	1904	330
75	Geo. J. Maher	164	[c] 63	15	.....	26	1899	100

[a] Trap; schist; trap. [b] Till; hardpan. [c] Hardpan; black shale. [d] Sand; quicksand.

Springs in Bloomfield.

Map No.	Owner.	Elevation above sea level.	Yield per minute.	Amount used per day.	Improvements.
		Feet.	*Gallons.*	*Gallons.*	
1	Adams	140	.....	40	
3	W. Waugh	150	0.5	20	
25	A. Kelly	199	11	150	Compressed-air system; gas engine.
29	Connecticut Children's Aid	290	10	.....	Piped to buildings.
35	Gillmartin	165	4	400	
47	W. C. Hubbard	130	.75	.....	Piped to house.
57	W. C. Wade	140	.5	.....	
67	P. C. Banfield	90	.....	.....	

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Dug wells in Bloomfield.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used per day.	Depth to rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*
4	.....	Flat.....	185	32	30	155	.....	.....	.....
5	.....	Flat.....	185	19	.....	.....	(a)	.....	.....
6	Victor Brzenski...	Hill.....	227	20	17.5	.....	(a)	.....	6
7	.....do.....	Hill.....	225	9	7.5	117.5	.....	.....	.....
8	Belzinski.....	Slope....	200	20	15	185	.....	.....	.....
9	Howard Bloomer..	Slope....	225	16	9	216	.....	.....	.....
14	.....	Flat.....	155	17	11	144	.....	.....	.....
15	L. M. Banning....	Flat.....	158	20	16	142	.....	20	.....
16	.....	Slope....	285	13	10	275	.....	.....	.....
17	.....	Slope....	275	11	9	266	.....	.....	.....
18	A. C. Case.....	Hill.....	210	9	5	205	.....	.....	.....
19	.....do.....	Hill.....	210	11	7	203	.....	10	.....
23	.....	Hill.....	145	21	14	131	.....	.....	.....
24	A. Kelly.....	Slope....	195	25	15	180	.....	0	15
26	Eugene Barnard..	Slope....	200	30	.....	.....	.....	45	.....
27	.....	Slope....	190	10	8	182	.....	.....	.....
28	H. M. Myrick.....	Valley ..	200	25	24	176	.....	20	.....
30	O. Johnson.....	Slope....	185	17	15.5	169.5	.....	.....	.....
31	.....	Slope....	200	16	14	186	(a)	6	.....
32	Burnham.....	Slope....	195	20	14	181	(a)	.....	13
33	.....	Slope....	195	15	13	182	.....	50	.....
34	F. W. Legeyt.....	Slope....	200	14	13	187	(a)	20	.....
36	.....	Hill.....	178	21	17	161	.....	.....	.....
37	W. J. Cooley.....	Slope....	125	16	11	114	.....	25	.....
38	C. H. Cooley.....	Slope....	165	22	21	144	(a)	0	.....
39	Capin Bros.....	Hill.....	165	15	11	154	.....	.....	.....
40	Geo. Humphrey...	Hill.....	127	14.5	12	115	.....	.....	.....
41	W. P. Francis.....	Hill.....	135	33	30.5	104.5	.....	.....	.....
42	C. F. Foster.....	Flat.....	115	10	8	107	.....	12	.....
43	.....do.....	Flat.....	115	7	5	110	.....	2	.....
45	Alfred Marshall....	Flat.....	135	22	21.5	113.5	(a)	0	.....
48	W. C. Hubbard....	Hill.....	120	18	14	106	.....	5	.....
49	Eddy.....	Hill.....	120	18	14	106	.....	5	.....
56	.....	Flat.....	125	19	7.5	117.5	.....	30	.....
58	Mohloiz.....	Flat.....	120	13	8.3	111.7	.....	10	.....
59	O. Blasig.....	Flat.....	130	10	7	123	.....	30	.....
60	Mills.....	Flat.....	160	16	13.5	146.5.	.....	10	.....
62	Louise Astermill...	Flat.....	140	18	16.5	123.5	.....	20	.....
65	A. A. Mills.....	Hill.....	145	43	15	130	4	15	.....
66	J. Burnham.....	Slope....	125	11	8	117	.....	.....	.....
68	A. Christ.....	Flat.....	130	14.5	11.5	118.5	.....	.....	.....
69	A. M. Spenser.....	Flat.....	110	18	8.5	101.5	.....	35	.....
70	G. R. Olin.....	Flat.....	100	20	19	81	.....	.....	.....
71	.....	Flat.....	110	14	11	99	.....	.....	.....
73	Rathman.....	Flat.....	115	30	27	88	.....	10	.....
74	Wm. Rockwell....	Slope....	150	13	10	140	.....	.....	.....

[a] Well goes dry.

Driven wells in Bloomfield.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.
			Feet.	*Feet.*	*Inches.*	*Gallons.*
2	Barns.....	Flat.....	180	25	1.5	2.5
10	Griffen-Newberger Tobacco Co.....	Flat.....	180	15	.....	.....
11	.....do.....	Flat.....	180	15	.....	.....
12	.....do.....	Flat.....	180	15	.....	.....
13	.....	Flat.....	.....	.....	.....	.....
63	.....	Flat.....	130	10	.....	.....
64	Mix.....	Flat.....	120	13	.....	.....

QUALITY OF GROUND WATER.

The water from the 63-foot well of George J. Maher was analyzed as indicated in the accompanying table and was found to be hard and rather high in its content of chlorine.

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Analysis of water from the 63-foot drilled well of George J. Maher (Pl. IX, No. 75), collected June 17, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	722
Total hardness as $CaCO_3$	387
Silica (SiO_2)	10
Iron (Fe)	1.5
Calcium (Ca)	95
Magnesium (Mg)	26
Carbonate radicle (CO_3)	Tr.
Bicarbonate radicle (HCO_3)	75
Sulphate radicle (SO_4)	19
Chlorine (Cl)	245

STAMFORD.

POPULATION AND INDUSTRIES.

The town of Stamford is in the southwest part of Fairfield County, bordering Long Island Sound. It is reached by the New York division of the New York, New Haven & Hartford Railroad, which has stations at Stamford and Glenbrook; by the New Canaan branch of the same road, with stations at Glenbrook, Springdale, and Talmadge Hill; by steamboat from New York; by stage from Pound Ridge and Bedford in New York, Long Ridge, High Ridge, and North Stamford; and by trolley from Darien, Greenwich, Sound Beach, Springdale, Shippen Point, and Glenbrook. Post offices are maintained at Stamford, Glenbrook, and Springdale. Rural free delivery covers outlying parts of the town.

The area of Stamford is 38 square miles. It was settled in 1641 under New Haven jurisdiction, was named in 1642, and was incorporated under Connecticut in October, 1662.

The population of the town in 1910 was 28,836; of the city, 25,128. The population of the town from 1756 to 1910 is shown in the following table:

Population of town of Stamford, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	2,768			1840	3,516		
1774	3,563	22		1850	5,000	44	
1782	3,834	8		1860	7,185	44	
1790				1870	9,714	35	
1800	4,352			1880	11,297	16	
1810	4,440	2		1890	15,700	40	
1820	3,284		26	1900	18,839	20	
1830	3,707	13		1910	28,836	53	

The chief industries are agriculture and the manufacture of artificial leather, bronzes, camphor, carriages, cocoa, cod-liver oil,

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chocolate, drugs, dyestuffs, extracts, furs, hats, ink, insulated wire and cable supplies for rubber manufacturers, iron castings, japans and varnish, knit goods, locks, machinery, music boxes, Paris white, paints, pianos, pottery, shirtwaists, shoes, stoves, thread, and whiting.

TOPOGRAPHY.

The surface of the town is, in general, rugged. Elevations exceeding 100 feet are found within a quarter of a mile of the shore, and the hills increase in height northward, reaching an elevation of 570 feet on the north boundary in the northwest corner of the town. The topography of Stamford has been produced by the dissection of a plateau and the subsequent deposition of glacial drift over the surface. With the possible exception of a few drift mounds, the hills are remnants of an old highland gashed by innumerable stream valleys, which are lined with glacial deposits. (See Pl. X, in pocket.)

The principal rivers are the Rippowam, the Mianus, and the Noroton. The Mianus is the largest stream, but it lies near the boundary in the northwestern corner of the town and its drainage area in Stamford is comparatively small. In the vicinity of Riverbank the valley of this stream is constricted and the river falls 60 feet in less than a quarter of a mile, but north of Riverbank for a distance of 2 miles there is a flat, marshy valley floor, the remnant of a small glacial lake. Noroton River forms the east boundary of the town from 1½ miles above Springdale to the Sound, and it also drains only a small part of Stamford. Rippowam River passes through the town from north to south, and, with its tributaries, drains the greater part of it.

About one-fourth the area of Stamford, comprising most of the slopes, is forested. In the northern part of the town woods extend well into the valleys. The hilltops are generally bowlder-strewn grass lands. The plowed lands comprise less than one-quarter of the town, the small gardens and grain fields being separated by relatively large meadows.

WATER-BEARING FORMATIONS.

Bedrocks.—The indurated rocks of Stamford are crystalline schists and gneisses. They are exposed in many places and are encountered in all of the drilled wells, in many of the dug wells, and even in the excavations for buildings in the city. The rock surface is uneven and appears to correspond very closely to the topography of the present land surface. Almost all the hills reveal rock ledges on their slopes and crests, and in many places the rivers have rock beds. All these rocks are cut by joints that afford passage for water, which can frequently be seen trickling from them in the exposures along

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the roadsides. For further discussions of water in the bedrock see page 40.

Till.—Unstratified glacial deposits are found in all parts of the town except in some places along the shore, where beach sand has accumulated, and in narrow belts along the principal streams, where stratified drift is found. Unstratified deposits abound in bowlders, some of which are 2 feet in diameter, and over large tracts the bowlders lie at the surface so close together as to almost touch. Where the land is tilled they have been in large part cleared away and used in building fences. In a few places the mantle of till is 60 to 75 feet thick; in general it is thin, and the average thickness is probably not more than 20 feet. Rocks are exposed in practically all the hills and in most places the streams have rocky beds. Many of the domestic water supplies in the rural districts are obtained from the till.

Stratified drift.—The stratified drift occurs in a manner suggesting that it was deposited by glacial streams that occupied valleys practically identical with the valleys that contain the present streams. Kamelike deposits of stratified material are found in the northern part of the town, and stratified deposits form a conspicuous terrace in the southern part of the town, just north of the city of Stamford, on the east side of Mill River. The shore line is digitate, and the inner margins, as, for example, the shore of Wescott Cove, are sand beaches; the projections, however, such, for example, as Shipman Point, are covered with till. The gravel deposits in the northern part of the town and immediately north of the city should afford good supplies of water to driven wells, the conditions being especially favorable in the vicinity of Springdale and Glenbrook. For discussion of the occurrence of water in stratified deposits see page 15.

SURFACE-WATER SUPPLIES.

The topography of the north half of Stamford is favorable to the utilization of surface-water supplies. Streams and springs are numerous, and the slopes are steep and thinly covered with drift, affording suitable conditions for controlling the run-off. The reservoir of the Stamford water department is situated in the valley of Rippowam River at North Stamford. A small dam has been constructed on a short tributary of the Mianus in the northwest corner of the town to control a seldom-used emergency supply of 14,000,000 gallons for Greenwich.

Sites at which impounding reservoirs could be built are numerous in the northern part of Stamford. The best site is probably that in the valley of Mianus River in the vicinity of Riverbank.

No sewage enters the streams in the northern part of Stamford except that from the usual rural settlements, but owing to the rough

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topography and the steep slopes a large proportion of domestic and farm wastes is washed into the streams.

GROUND-WATER SUPPLIES.

Almost all the shallow wells in Stamford are sunk in glacial till and most of them either penetrate or closely approach bedrock. In the areas of deeper drift, as in the southeast part of the town, a bed of coarse gravel with some clay furnishes a good permanent supply wherever wells have penetrated it. Where the drift is thinner water is obtained chiefly from a zone of comparatively thin deposits just above the rock. The rough surface affords numerous small drainage slopes which are favorable for both dug wells and springs, and few wells fail in dry seasons.

In the deeper valleys, such as that of Noroton River, water is easily obtainable and is abundant, as these valleys generally contain deposits of sand and gravel. A well sunk by Mr. Waterbury, in Glenbrook, illustrates a practical method of procuring good supplies in such places. The well was made by driving a 6-inch well casing through 30 feet of sand to a bed of gravel. It was completed in a few hours and its yield was larger than could be determined by the methods commonly employed in pumping drilled wells. It is situated near Noroton River and ends at a level below the bed of the stream.

The range in depth of 139 shallow wells examined in this town lies only between 10 and 30 feet and the average depth is about 20 feet. The average yield, as computed from reports on 7 wells, is 3.7 gallons a minute, but the true average of all the wells would probably be less than 3 gallons a minute. Out of 35 wells, including none that were unused, the average daily consumption was found to be about 20 gallons to the well.

Of the wells examined 11 were said to have failed in dry seasons, and 24 were said never to have failed. No information was obtained on this point concerning the remaining 104 wells.

All the drilled wells in Stamford of which records were obtained end in crystalline rocks. With few exceptions, these wells yield water that is sufficient and suitable for domestic use. The number of drilled wells in the city of Stamford is relatively large, notwithstanding the fact that city water is abundant, because some people using large quantities of water consider it cheaper to obtain water from wells than from the public system. The higher parts of the city are not reached by the gravity system in use, and although pumping is resorted to in some places, drilled wells are commonly used instead. The average depth of 31 of the drilled wells in Stamford is 208 feet, the deepest being 454 feet and the shallowest 75 feet. The yields of 24 wells range from 3 to 75 gallons a minute and average 30 gallons.

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The average daily consumption from 13 wells was found to be about 400 gallons.

Owing to favorable topographic conditions there are many springs along the streams and on the hillsides, but practically all fluctuate more or less with the seasons. The yield rarely exceeds 2 gallons a minute and the average is considerably less than 1 gallon. A number of such springs are utilized for domestic supplies and a few, such as Varuna Spring, furnish water that is sold. All the springs that were examined in Stamford are gravity springs situated on hillsides or at the foot of slopes and draw water from the drift.

PUBLIC WATER SUPPLIES.

Stamford is supplied with water chiefly from a reservoir in the basin of Rippowam River, near North Stamford, but reserve supplies are stored in Mead Pond and Trinity Lake, both in Pound Ridge, New York. The main reservoir has an area of 114 acres, an average depth of 13 feet, and a capacity of 512,000,000 gallons. The capacity of Mead Pond is 80,000,000 gallons, and that of Trinity Lake is 450,000,000 gallons. About 20,000 inhabitants are supplied with water from this system and the consumption amounts to 2,000,000 gallons a day, or 100 gallons per capita. The water is gathered from an area of 22 square miles and suffices to maintain an overflow at the dam during most of the year. In the summer of 1910 the water in the main reservoir was drawn to 4 feet below the crest of the dam, but even then more than three months' supply was in the reservoir when the rains came and filled it to overflowing.

Springdale is supplied from two drilled wells, one of which has a surface elevation of 140 feet, is 454 feet deep, and yields 50 gallons per minute. The following log of this well was furnished by the driller:

Log of drilled well at Springdale waterworks.

	Thickness.	Depth.
	Feet.	*Feet.*
Bowlder clay	16	16
Granite	84	100
"Hard glassy rock" (quartzite)	300	400
"Soft black micaceous rock"	54	454

To insure against emergencies occasioned by fires or disability of pumps the second well was drilled. This well, which was completed in November, 1911, has a surface elevation of 90 feet, is 510 feet deep, and yields 45 gallons a minute. About 300 people are supplied from the Springdale system, and the daily consumption is 15,000 gallons, or 50 gallons per capita.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Stamford is presented in the following tables:

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Dug wells in Stamford.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used, per day.	Depth to rock.	Section.	Wall.	Cover.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*			
3	George Webber	Slope	60	28	12	68		0		Till	Stone	Open.
6	George W. Northrop	Hill	75	26	13	62	Good.	50		Till, gravel	Stone	Plank.
7	L. Brownfield	Hill	60	23	17	43				Till	Cement	
10	Kennedy	Slope	80	23	12	68		18		Till	Stone	
15	J. C. Woefel	Slope	100	23	20	80		0		Till	Stone	Open.
16		Flat	107	28.5	21	86		5		Till	Stone	Open.
18	W. A. Schaz	Slope	140	26	19	121	(b)			Till	Stone	Open.
19	McConnel	Hill	135	17	9	126		15	17	Till	Stone	Plank.
20		Hill	154	21	17	137	2			Till		
21	Jenkins	Hill	160	24	16	144	(b)			Till	Stone	Open.
22		Hill	200									Plank.
23	E. J. Louis	Slope	280	30			15			Till		Concrete.
25		Hill	270	28	13	257		0		Till	Stone	Open.
26	L. O. Murray	Slope	240	18	10	230		15		Till	Stone	Open.
28	W. L. Havery	Valley	230	17	2.5	227.5		10		Till	Stone	Open.
29		Hill	230	19	14	216				Till		Open.
30		Slope	233	17	15	218				Till	Stone	
31		Hill	370	16	13	357	(b)			Till	Stone	Open.
32	E. Weed	Hill	390	18	14.5	375.5				Till	Stone	Open.
34		Slope	325	26	18	307		50		Till	Stone	Plank.
36		Plain	300	18	13	287				Till	Stone	Open.
37		Plain	305	15	11	294	2	10		Till	Stone	Open.
40	George Jones	Slope	270	20	16	254		0		Till	Stone	Open.
41		Slope	385	20	15	370				Till		
42		Hill	240	22	15	225				Till	Stone	Open.
43	C. H. Crandall	Slope	450	24	17	433		15		Till	Stone	
44	W. H. Dann	Slope	425	18	13	412		10		Till	Stone	Open.
45		Hill	225	18	14	211				Gravel		
46		Slope	300	14	10	290				Till	Stone	Open.
47	S. Dann	Slope	375	19	14	361				Till	Stone	Open.
48	John Serrach	Slope	380	19	13	367				Till	Stone	Open.
49		Slope	360	23	16	344				Till	Stone	Open.
50	S. C. Brown	Plain	320	22	16	304				Till	Stone	Open.
51a	Town farm	Slope	287	20	14	273		0		Till	Stone	Plank.
53		Hill	335	26	18	317	(b)	12		Till	Stone	Open.
54		Slope	325	21	15	310		0		Till	Stone	Open.
55		Hill	270	23	14	256				Till	Stone	Open.
56		Slope	280	19	11	269				Till	Stone	Open.
57		Hill	260	21	9	251		8		Till	Stone	Open.
58		Hill	265	22	11	254		10		Till	Stone	Open.
59	George Heinze	Hill	275	27	15	260		0	17	Till, rock		Plank.

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60	....do	Hill	275	38	15	260		150	30	Till, rock		
63	Garison	Hill	250	26	11	239				Till	Stone	Open.
64		Hill	240	33	13	227		12		Till	Stone	Open.
65	P. B. Glasby	Slope	220	16	8	112	2			Till		
66	....do	Plain	228	18	9	119				Till		
67		Slope	235	23	16	219				Till	Stone	Open.
68		Slope	210	10	4	206		0		Till	Stone	Open.
69	R. M. Gillespie	Plain	218	21	10	208				Till	Stone	Open.
70		Plain	190	20	8	182				Sand	Stone	Shed.
71		Slope	150	28	18	132		0		Gravel	Stone	Open.
72	J. J. Lacy	Slope	125	20	15	110				Gravel	Stone	Open.
73	Gutzon Borglum	Flat	120									
75		Hill	140	18	12	128		0		Till	Stone	Open.
76		Hill	138	15	9	129		0		Till	Stone	Open.
77	H. E. Shockley	Hill	150	26	14	136				Till	Stone	Open.
78	W. Heinze	Hill	160	24	14	146	2	15		Till	Stone	Plank.
79	Frank Lockwood	Hill	175	23	18	157		0	6	Till, rock	Stone	Open.
86	Mrs. O'Toole	Hill	210	30	10	200			13	Till		
87	Dr. Milky	Hill	205	[c] 28	14	191		25		Till	Stone	Shed.
88		Hill	200	23	14	186	(b)	15		Till, rock	Stone	Open.
90	R. L. Case	Slope	135	25	8	127		40		Till	Stone	Plank.
91		Valley	90	16	9	81		0		Till	Stone	Plank.
94	A. E. Mitchell	Plain	145		10	135		0		Till	Stone	Plank.
95		Hill	60	26	15	45				Till	Stone	Lattice shed.
96		Flat	45	19	8	37		0		Till	Stone	Open.
97		Hill	62	17	13	49		0		Till	Stone	
98	G. W. Briggs	Slope	125	20	12	113		15		Till	Stone	Open.
99		Slope	65	20	14	51				Gravel	Stone	Open.
100		Slope	70	18	11	59				Sand, gravel	Stone	Open.
101	Mrs. A. L. Michael	Slope	175	15	10	165		0		Till		
102	O. D. Weed	Slope	200	21	15	185				Till	Stone	Open.
105	Norman Sherwood	Valley	140	15	8	132		15	12	Till, rock	Stone	Open.
106	C. Lockwood	Valley	155	19	13	142				Till	Stone	Open.
107		Slope	140	15	8	132		10		Till	Stone	Open.
108		Slope	143	14	6	137				Till	Stone	Open.
109		Slope	160	18	11	149				Till	Stone	Open.
110	S. Alvin Piza	Hill	90	26	18	72	(b)			Gravel	Stone	Plank.
111		Slope	65	18	12	53		10		Gravel, rock	Stone	Open.
112		Slope	90	20	13	77		0		Till	Stone	Open.
113		Slope	90	23	16	44				Till	Stone	Open.
115	George Marshall	Hill	185	20	14	171		10		Till	Stone	Open.
116	F. Reilly	Hill	190	17	11	179				Till		
117	John Connor	Hill	120	25	7	113				Till		

[a] Consists of—

	Feet.
Humic soil	1
Clay	6
Loam	3
Yellow clay	10
Hardpan	2
Gravel	4

[b] Well goes dry.
[c] Two feet of water at low mark.

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Dug wells in Stamford—Continued.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Yield per minute.	Amount used, per day.	Depth to rock.	Section.	Wall.	Cover.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*			
118	Town pest house	Valley	90	20	13	77		0		Till	Stone	Open.
120	A. T. Simcox	Slope	95	18	13	82				Sand, gravel.	Stone	Open.
121		Plain[a]	60	14	7	53				Till	Tile	Plank.
122		Hill	80	30	27	53	[b] 2	25		Till	Stone	Open.
124		Plain	250	21	12	238	1	10		Till, rock	Stone	Open.
125		Slope	328	28	11	317				Till	Stone	Open.
126		Valley	220	15	10	210		30		Till	Stone	Open.
127		Plain	240	12	7	233		7		Till, rock	Stone	Open.
128	F. Nolan	Plain	270	11	14	256				Till	Stone	Open.
129	E. Montaber	Slope	345	21	6	334		10		Till	Stone	Open.
130		Hill	420	12	19	411				Till		Open.
131		Hill	435	15	11	424		0		Till		
132		Slope	340	18	11	329				Gravel, rock.	Stone	Open.
133	Mrs. T. Cooper	Slope	340	26	11	329				Sand	Stone	Open.
134		Slope	345	18	12	333				Sand		Open.
135	E. Dutcher	Slope	347	14	11	336				Sand	Stone	Open.
136	C. Rivers	Plain	345	12	7	338				Till, rock	Stone	Open.
137		Hill	400	17	12	388				Till	Stone	Open.
138		Hill	420	23	17	403				Till	Stone	Open.
139		Slope[c]	438	15	11	427				Till	Stone	Open.
140		Hill	420	24	20	400				Till	Stone	Open.
141		Hill	425	19	15	410				Till		
142		Slope	410	24	19	391				Till	Stone	
143	Beecher	Hill	460	21	15	445	([b])			Till	Stone	Open.
144		Hill	260	20	15	245		10		Till	Stone	Open.
145	Tipmon	Plain	190	12	5	185				Alluvium	Stone	Open.
146	N. W. Smith	Slope	310	18	14	296				Till		Plank.
147		Slope	235	16	12	223				Till		
149		Plain	190	17	12	175				Till		Open.
150	B. F. June	Slope	190	12	8	182				Till		
151		Slope	175	18	11	164		7		Till	Stone, concrete.	Open.
152	J. Studwell	Plain[d]	160	13	5	155				Till	Stone	Open.
153		Hill	200	18	14	186				Till	Stone	Open.
154	Mrs. A. June	Plain	220	14	11	210				Till	Stone	Open.
155	A. Marshall	Slope	280	18	15	265			9	Till, rock	Stone	Open.
156	P. Horton	Slope	275	20	14	261				Till	Stone	Open.
157		Hill	217	16	13	204				Till	Stone	Open.
158		Hill	250	11	3	247		0		Till	Stone	Plank.
159	Church	Hill	230	10	2	228				Till	Stone	Open.
160	J. Ryle	Hill	230	18	8	222		0		Till		

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161	Denbrook farm	Hill	235	16	4	231				Till	Stone	
162	High View farm	Hill	237	15	3	234				Till	Stone	Open.
163	Frank Weed	Slope	180	20	11	169				Till, rock	Stone	Open.
164		Slope	165	26	16	149		50		Till	Stone	
166	Mrs. Packer	Hill	335	43	6	329			10	Till, rock		Plank.
169		Slope	138	18	14	124		15	18	Till, rock		Plank.
170	J. Clason	Hill	220	23	15	205				Till	Stone	
171	C. Gildenmerster	Hill	220	18	11	209				Till	Stone	
172	Herbert G. Ogden	Slope	190	18	15	175				Till	Stone	
181	W. D. Baldwin	Shore	17	16	6	11				Till	Stone	Open.
183		Hill	155	30	9	146				Till		
185	Frank Lockwood	Valley	160	13	6	154		8		Till		Open.
186		Hill	200	21	15	185				Till		Open.
187	Mrs. Packer	Hill	290	17	2	288	(b)	0		Till	Stone	Plank.
188		Slope	160	16	11	149		15	9	Till, rock	Stone	Open.

[a] Edge of brook. [b] Well goes dry. [c] Slope fromout buildings toward well. [d] Swampy surroundings.

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Drilled wells in Stamford.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Diameter.	Drilled in year—
			Feet.	*Feet.*	*Galls.*	*Galls.*	*Feet.*	*Inches.*	
1	E. B. Hoyt (residence).	Hill	90	200	45		60	8	1909
2	E. Y. Webber	Slope	60	150	35	500	40	8	1906
4		Slope	60						[a] 1911
5	George Webber	Slope	55	208	40	500	12	8	1904
8	Hartlett	Slope	80	80	2	50	18		1904
9	Powell	Slope	85	90	3	50	10		1907
11	Fred Berg	Hill	130	400	10		0		1910
12	McDougall	Valley	75	95	4	80	0		
13	Springdale Water Co.	Slope	100	454	48	12,000 to 15,000	16		
14	do	Hill	150	510	45		12		1911
24	W. M. Raymond	Slope	270	100	+ 7		[b] 45	6	
33	Advocate Co.	Flat	28	250	20	2,000	20		1896
38	W. W. Daschield	Hill	290	301		200			
39	do	Slope	270	90	[c] 6	0			1905
51	Town Farm	Slope	300	200	50		0		1897
52	Mrs. Towns	Hill	310	130	25	0	30		1900
62	Varuna Spring Water Co.	Slope	220	310	50			8	
74	Andrew Boyd	Hill	215	183	4		0		[d] 1909
80	J. N. Robbins	Hill	310	275	25	4,000	50		1909
81	Varian	Hill	310	150	20		40	6	1899
82	O'Flinn	Hill	290	275	12			6	
83	Rothchilds	Hill	290	183	70		60	6	1901
84	Robert Kerr	Hill	240	176					
85	J. C. Bickel	Hill	230	153	15	50			
89	Kans Bros	Slope	140	200		400			1910
92	A. E. Mitchell	Hill	160	300		100			
93	Mrs. Holbrook	Hill	160	412	5				
103	H. Palmer		200	300	3		0		1903
104	James Weed	Hill	195	155	10	75	0		1901
114	Stamford Sanatorium.	Valley	40	135	50	30,000	20		1897
119	Mrs. Gross	Slope	135	150	5		0		1896
123	E. P. Brown	Hill	290	132	4	40	20	6	1910
148	W. H. Childs	Hill	230	205	8	60	0		
165	Mrs. Gurtrude Hall	Hill	315	129	8	0	20	6	1911
168									[a] 1911
173	H. G. Ogden	Slope	190	310	10	60	8	8	
174	Dr. Morris	Ravine					0		[a] 1911
175	Mayer Ice Co	Valley	35	104	75				
176	Diamond Ice Co	Flat	25	90			50		
177	A. Lynch	Flat				[e] 0			
178	E. B. Hoyt (market)	Flat	30	140	40		40		
179	Mrs. Alexander	Shore	15	192		15,000	10		
180	W. D. Baldwin	Shore	17	250	[f] 7				
182	Crane	Hill	155	300	30		60		1902
184	Miss Smith	Hill	265	200	15		50	6	1897
189	C. Eckert	Slope	140	183	70	100	25		1902
190	Stamford Gas & Electric Co.	Shore	12	300		[g] 0	20		1911
191	do	Shore	12	250		[g] 0	20		1911
192	do	Shore	12	40		[g] 0	20		1911

[a] Incomplete when visited.
[b] Till.
[c] Well is now dry.
[d] Well cost $500.
[e] Water is foul.
[f] Salt water is obtained after one-half hour's pumping.
[g] Water is salty.

Springs in Stamford.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Improvements.
			Feet.	*Gallons.*	
17	Schofel & Miller	Slope	120	0.5	
27	A. Hatch	Slope	226	10	Concrete reservoir.
35	C. A. Bruce	Foot of slope	330	4	Piped to horse trough.
61	Varuna Spring Water Co.	Slope	230		
167	J. B. Strang	Foot of slope	230	1	

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QUALITY OF GROUND WATER.

Analyses of water from three drilled wells in Stamford are given in the accompanying table. They represent moderately mineralized, moderately hard waters low in content of sulphate and chlorine.

Analyses of water of drilled wells in Stamford.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2	3
Total solids at 180° C	127	250	138
Total hardness as $CaCO_3$	63	133	71
Silica (SiO_2)	12	.....	.....
Iron (Fe)	Tr.	.10	Tr.
Carbonate radicle (CO_3)	.0	.0	.0
Bicarbonate radicle (HCO_3)	106	131	87
Sulphate radicle (SO_4)	14	36	23
Chlorine (Cl)	2.4	19	8.4

1. Well of Kans Bros. (Pl. X, No. 89), 200 feet deep; sample collected June 26, 1915.
2. Well of Mrs. Gross (Pl. X, No. 119), 150 feet deep; sample collected June 26, 1915.
3. Well of C. Eckert (Pl. X, No. 189), 183 feet deep; sample collected June 26, 1915.

GREENWICH.

POPULATION AND INDUSTRIES.

Greenwich is in the southwest corner of Connecticut, in Fairfield County. It is reached by the New York division of the New York, New Haven & Hartford Railroad (stations at Greenwich, Cos Cob, Riverside, and Sound Beach); by steamboat from New York daily during the summer and triweekly during the winter; by stage from Port Chester, N. Y., to the villages of Glenville and Pemberwick; and by trolley from Port Chester and Stamford. Post offices are maintained at Greenwich, Cos Cob, Glenville, Riverside, and Sound Beach.

Greenwich was settled by the Dutch in 1640 and was acquired by Connecticut from New York in 1662. The area of the town is 49 square miles.

The population of the town of Greenwich in 1910 was 16,463, of the borough, 3,886. The population of the town from 1756 to 1910 is shown in the following table:

Population of Greenwich, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	2,051	.....	.....	1840	3,921	4	.....
1774	2,776	37	.....	1850	5,036	27	.....
1782	2,623	.....	5	1860	6,522	30	.....
1790	.....	.....	.....	1870	7,644	17	.....
1800	3,047	.....	.....	1880	7,892	3	.....
1810	3,533	16	.....	1890	10,131	28	.....
1820	3,790	7	.....	1900	12,172	20	.....
1830	3,801	3	.....	1910	16,463	36	.....

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The principal industries are agriculture and the manufacture of belting, woolens, hardware, etc. The town is a resort for New York City people during the summer, and there are many large country estates not essentially devoted to agriculture.

TOPOGRAPHY.

Greenwich is a highland town and its topography is characteristic of the highland areas. The land rises rapidly from the shore and reaches an elevation of 615 feet on the northwest boundary. In general, the topography is less rugged in Greenwich than in the adjoining town of Stamford; the divides are broader and the slopes gentler, but the relief is somewhat greater. In the southern half the average relief is about 100 feet; in the northern half about 250 feet.

The principal streams in Greenwich are Mianus River, Byram River, Greenwich Creek, and Horseneck Brook. Byram River, the largest, drains about half of the town. Greenwich Creek and Horseneck Brook receive most of the drainage from the eastern half. Mianus River enters the town about 2 miles above its mouth and receives very little drainage in Greenwich. The stream valleys are narrow, and there is an average fall of about 50 feet to the mile. The effect of glaciation is shown by five swampy areas, the remnants of small glacial lakes. (See Pl. X, in pocket.)

WATER-BEARING FORMATIONS.

Bedrocks.—Crystalline schists, gneisses, and granites constitute the larger part of the rock floor in Greenwich, but a small area in the northwest corner of the town is underlain by crystalline limestone. As a result of earth movements in past geologic time the bedrocks of this region have been thoroughly fractured throughout the upper zone. Irregular cracks extend from the surface to depths of several hundred feet and they constitute the only important source of water in these rocks. Cracks wide enough to allow a ready passage of water are, however, exceedingly rare at depths greater than about 300 feet, and it is therefore not usually advisable to sink wells deeper.

The bedrocks everywhere lie near the surface and are exposed in a great many places. Some varieties of gneiss weather very readily, and where these are exposed, as, for example, in the railroad cuts between the Stamford and Greenwich railroad stations, they form comparatively soft and shaly masses. Most of the rocks, however, have withstood weathering to such an extent that their appearance is not altered even in localities where they have been long exposed to attack of the atmosphere.

Till.—Till, which consists of mixtures of bowlders, sand, and clay, overs all the higher lands and is the predominating rock cover. It

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ranges in thickness up to about 80 feet, but the average is not more than 25 feet. On most of the hills the covering of till is thin and bedrock protrudes in many places, but some of the hills consist almost entirely of till.

Stratified drift.—Stratified drift, consisting of layers of sand and gravel without bowlders, lies at the surface along the principal stream courses, but it is generally thin, exceeding 30 feet in thickness at only a few places. This material is most conspicuous in the vicinity of Round Hill. Deposits of beach sand occur at a few places along the shore, but in general the till extends down to the water line. (See p. 15.)

SURFACE-WATER SUPPLIES.

The principal surface-water developments in Greenwich are on Putnam, Rockwood, and Converse lakes, the last two "lakes" being in fact artificial reservoirs formed by the construction of dams. Putnam and Rockwood lakes supply the Greenwich waterworks. Converse Lake is said also to have been intended for the municipal system, but it has been used for the public supply only in emergency. Putnam Lake is in the upper part of the basin of Horseneck Brook, at an elevation of about 282 feet above sea level. Rockwood Lake is at the head of Greenwich Creek near Stanwich, at an elevation of about 300 feet above sea level. Converse Lake is at the head of the east branch of Byram River near Banksville, its upper lobe extending a short distance into New York. There are a few power plants on Byram River and at North Mianus on Mianus River

GROUND-WATER SUPPLIES.

In the rural districts of Greenwich water is most commonly obtained from dug wells. Forty dug wells, ranging in depth from 11 to 36 feet and averaging 16 feet, were examined. Thirty-four of these wells end in till and five in sand; one ends at the rock surface, and seven penetrate rock. The depth to rock in eight wells ranges from 8 to 26 feet and averages 16 feet. The depth to water, as determined by measurements of 40 wells, ranges from 7 to 24 feet and averages 12 feet. The average yield, determined by measurement of five wells, is 3 gallons a minute, or about 4,500 gallons a day, the greatest yield being 4 gallons and the least 1.5 gallons. Reports of the quantity of water used from 24 wells show a maximum under 40 gallons a day and average about 20 gallons. Four of the wells examined are said to fall frequently.

Twenty-four drilled wells, ranging in depth from 70 to 1,000 feet and averaging 331 feet, were examined; excluding eight wells that are 500 feet or more in depth, the average depth is 233 feet. The position of bedrock in 21 wells ranges from the surface to 100 feet

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below, and, including 13 wells which start on rock, average depth to rock is 16 feet. The maximum yield reported was 60 gallons a minute, and the average, excluding two dry wells, is about 12.5 gallons.

The daily consumption reported for seven wells ranges from about 25 to 500 gallons and averages about 180 gallons a well.

The average annual fluctuation of the water level in the wells of Greenwich, as determined from observations of four wells during 1912, is 9 feet, the greatest fluctuation being 12 feet and the least 6 feet. Wells situated on low flats generally show the least fluctuation, those on hillsides near the tops of slopes show the greatest fluctuation (fig. 2, p. 18). The average depth to the water table as determined from measurements of 40 wells in the town is about 12 feet. These measurements were made in June, 1912, when the water level was approximately at its average position.

PUBLIC WATER SUPPLIES.

The borough of Greenwich obtains water from two reservoirs in the central part of the town, one, Putnam Lake, in the valley of Horseneck Brook, and the other, Rockwood Lake, at the headwaters of Greenwich Creek. Putnam Lake covers 105 acres and holds 570,000,000 gallons. Rockwood Lake covers 106½ acres and holds 460,000,000 gallons. A reservoir with a capacity of 14,000,000 gallons is situated on a small tributary of Mianus River in Stamford, but has been rarely utilized. A drought during the winter of 1910 necessitated drawing temporarily from Converse Lake, a private reservoir at the headwaters of the east branch of Byram River near Banksville. All the water distributed by this system is purified by mechanical filtration. The average daily consumption is 5,000,000 gallons in summer and 3,000,000 gallons in winter.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Greenwich is presented in the following tables:

Dug wells in Greenwich.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
3	.....	Hill.....	60	12	7	53	.....	.....
5	George Clark.....	Slope....	85	11	8	77	.....	(a)
6	Mrs. S. E. Marshall.....	Hill.....	110	20	12	98	.....	.....
7	Wm. Wenzel.....	Hill.....	140	17	12	128	.....	.....
9	Chas. Perin et al.....	Valley ..	242	14	12	230	.....	.....
10	.....	Hill.....	280	28	25	255	.....	.....
11	.....	Slope....	345	13	10	335	.....	.....
12	W. Lockwood.....	Slope....	350	15	11	339	.....	.....
16	E. M. Hobby.....	Hill.....	485	23	15	470	10	a 4
17	.....	Slope....	400	18	16	384	.....	.....
18	.....	Slope....	400	12	10	390	.....	.....

a Well goes dry.

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Dug wells in Greenwich—Continued.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
25		Slope	85	16	9	76		
27		Slope	30	13	12	18		
31	G. Kennedy Todd	Flat	13	12	9	7		
32		Flat	15	16	8	7		
34		Flat	20	14	10	10		
35		Flat	15	12	9	6		
37		Slope	340	33	27	313		(a)
38	E. C. Converse	Plain	408	18	11	397		
39	W. H. Erhart	Valley	410	12	7	403		
40	L. Timmons	Hill	440	36	19	421		
41	Mrs. John Clark	Slope	516	23	19	497	6	2
42		Hill	480	16	11	469		
43	W. O. Dove	Slope	460	30	16	444		2.5
44		Hill	320	21	17	303		
45		Valley	250	13.5	7.5	242.5		
47		Slope	260	15	9	251		
49	Schoolhouse	Hill	345	20	8	237		1.5
50		Hill	300	13	10	290		
51	R. A. Strong	Hill	380	12	8	372	9	(a)
53	W. T. Carrington	Hill	500	21	10.5	489.5		
54	Daniel Ryan	Slope	430	13	10	420		4
55	D. M. Griffin	Slope	430	15	11	419		
57	King Street School	Hill	325	32	8	317	12+	
58		Slope	160	15	8	152		
59	A. J. Peck	Slope	140	30	24(?)	116(?)		
61	Lown	Hill	240	25	22	218		
63		Hill	250	19	14	236		
64		Valley	270	15	7	263		
65		Plain	240	11	10.5	229.5		

Map No.	Owner.	Amount used per day.	Depth to rock.	Section.	Wall.	Cover
		Gallons.	*Feet.*			
3		10	8	Till and rock	Stone	Open.
5	George Clark	12	10	Till and rock	Stone	Plank.
6	Mrs. S. E. Marshall	15		Till	Stone	Lattice shed.
7	Wm. Wenzel	15	15	Till and rock	Stone	Open.
9	Chas. Perin and others	25	14	Till and rock	Stone	Open.
10				Till	Stone	Open.
11		0		Till	Stone	Plank.
12	W. Lockwood	25		Till	Stone	Plank.
16	E. M. Hobby	25		Till	Stone	Open.
17		15		Till	Stone	Open.
18		20		Till	Stone	Plank.
25		20		Till	Stone	Open.
27		0		Till	Stone	Open.
31	G. Kennedy Todd			Sand	Stone	
32		0		Till	Stone	Plank.
34		20		Till	Stone	Open.
35		10		Till	Stone	Plank.
37				Till	Stone	Open.
38	E. C. Converse	10		Till	Stone	Open.
39	W. H. Erhart	40		Till	Stone	Open.
40	L. Timmons	0		Till	Stone	Plank.
41	Mrs. John Clark	25	22	Sand and rock	Stone	Lattice shed.
42		20		Till	Stone	Open.
43	W. O. Dove	25		Till	Stone	Open.
44		0		Till	Stone	Open.
45				Sand	Stone	Open.
47				Sand	Stone	Plank.
49	Schoolhouse	2		Till	Stone	Plank.
50				Till	Stone	Open.
51	R. A. Strong	0	10	Till and rock	Stone	Plank.
53	W. T. Carrington	0		Till	Stone	Open.
54	Daniel Ryan	20		Till	Stone	Shed.
55	D. M. Griffin	30		Till	Stone	Open.
57	King Street School	8	25	Till and rock	Stone	Plank.
58		15		Till	Stone	Open.
59	A. J. Peck		26	Sand and rock	Stone	Plank.
61	Lown	20		Till	Stone	
63					Stone	Open.
64				Till	Stone	Plank.
65		15		Till	Stone	Plank.

a Well goes dry.

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Drilled wells in Greenwich.

Map No.	Owner.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Drilled in year—
		Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*	
1	Mrs. Alexander	160	170	5	200		
2	H. O. Havemeyer	160	245	60			
4	North Mianus School	35	75	7	25	0	
8	Charles Perin and others	240	250	10		0	1912
13	Thomas Paten	360	[a] 104	2.5	100		
14	R. A. Elliott	500	300	36	500	62	
15	A. Barrett	520	150	3	300	10	1911
19	Booze	300	300	16		30	
20	H. C. Krothoff	230	1,000	30		0	1911
21	do	190	430	5		0	1912
22	Ely School	265	300	2		0	
23	do	258	300	8		0	
24	Greenwich Country Club	255	150	10		0	
26	Mrs. Judge McNowell	100	200	15	100	0	
28	Edward Sandreuter	80	203	6	50	0	1912
29	G. Kennedy Todd	12	70	4	0	0	
30	do	12	300	0	0	0	
33	Roberts	20	300	6		8	
36	Hotel	12	1,000	6?	0	10	
48	Griswold	325	405	22		90	
52	W. T. Carrington	500	800	30?		30	
56	Charles Purdy	425	200?	10		0	
60							
62	Lown	240	200	0		0	
67	A. P. Stokes	360	500	6		100	

[a] Diameter of well 6 inches.

Springs in Greenwich.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Amount used per day.	Improvements.
			Feet.	*Gallons.*	*Gallons.*	
46	De Craft	Slope	280	1.5	0	Concrete reservoir; shed.
66		Valley	235	8	30	Concrete cistern 8 by 12 feet; windmill.

QUALITY OF GROUND WATER.

No recent tests of water from drilled wells are available, but analyses of water from nine school wells, probably shallow, were made by the Connecticut State Board of Health in 1898.[1] According to those analyses the waters ranged in total solids from 52 to 109 parts, in total hardness from 15 to 44 parts, and in chlorine from 2 to 15 parts per million. If conditions here are similar to those around Hartford the waters of deep wells would be harder and would show a higher mineral content.

SALISBURY.

POPULATION AND INDUSTRIES.

Salisbury is in Litchfield County, in the northwest corner of the State. It is reached by the Central New England Railway, which

[1] Connecticut State Board of Health Rept. for 1898, pp. 291–296.

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has stations at Chapinville, Salisbury, Lakeville, and Ore Hill and which connects with the Berkshire division of the New York, New Haven & Hartford Railroad at Canaan, on the east border of the town. The Harlem division of the New York Central & Hudson River Railroad runs along the west border and connects with the Central New England Railway at Millerton. Post offices are situated at Salisbury, Chapinville, Lakeville, Ore Hill, and Lime rock.

Salisbury was incorporated in October, 1741. Its area is 61 square miles.

The population in 1910 was 3,522. The following table shows the population of the town from 1756 to 1910, inclusive:

Population of the town of Salisbury, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	1,100			1840	2,562		0.7
1774	1,980	80		1850	3,103	21	
1782	2,225	12		1860	3,100		.1
1790				1870	3,303	6	
1800	2,266			1880	3,715	12	
1810	2,321	2		1890	3,420		8
1820	2,695	16		1900	3,489	2	
1830	2,580		4	1910	3,522	1	

The principal industries are agriculture, mining and smelting iron ore, and manufacture of car wheels and pocketknives. About 15,200 acres of land are under cultivation and about 200 people are engaged in farming.

TOPOGRAPHY.

The west half of Salisbury is mountainous, the principal peaks being Bear Mountain, Gridley Mountain, Mount Riga, Lions Head, and Indian Mountain. East of the mountains a narrow central valley extends from the Massachusetts line southward to Sharon. The east boundary of the town is formed by Housatonic River. Between the Housatonic and the central valley, Miles Mountain, Toms Mountain, Mount Prospect, Gallows Hill, Forge Hill, Red Rocks, and Sharon Mountain produce a rugged topography. The highest point in the State of Connecticut, 2,355 feet above sea level, is on Bear Mountain. The lowest land in the town, about 530 feet, is on the Housatonic in the southeastern corner of the town. About 22,800 acres, or a little less than half of the total area of the town, is mountainous. The central valley, which comprises nearly all the agricultural land of the town, is about a mile in average width in the southern half of the town but broadens to nearly 3 miles north of Mount Prospect. (See Pl. XI, in pocket.)

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Nearly all the drainage reaches the Housatonic through Moore Brook, which occupies the central valley from Chapinville to Salisbury, where it joins Button Brook to form Salmon Creek, flows through a narrow pass at Limerock, and finally enters the Housatonic above Limerock station. The fall of Moore Brook between Chapinville and Salisbury is about 80 feet; of Salmon Creek from Salisbury to its mouth about 100 feet; and of Housatonic River between the Massachusetts line and the southern boundary of Salisbury, 130 feet. The following table shows the discharge of the Housatonic at Gaylordsville:

Monthly discharge of Housatonic River at Gaylordsville, Conn., for 1906–1909.[a]

[Drainage area, 1,020 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.		
1906.						
January	3,170	988	1,800	1.76	2.03	
February	4,630	788	1,630	1.60	1.67	
March	10,000	1,120	2,910	2.85	3.29	
April	8,930	2,460	4,780	4.69	5.23	
May	5,060	1,090	2,110	2.07	2.39	
June	2,370	928	1,630	1.60	1.78	
July	2,120	421	984	.965	1.11	
August	1,310	347	818	.802	.92	
September	876	296	554	.543	.61	
October	2,220	296	861	.844	.97	
November	1,980	550	992	.973	1.09	
December	1,440	686	958	.939	1.08	
The year	10,000	296	1,670	1.64	22.17	
1907.						
January	3,970	1,060	2,080	2.04	2.35	B.
February	1,370	816	1,120	1.10	1.14	B.
March	5,330	714	2,430	2.38	2.74	B.
April	3,350	1,830	2,340	2.29	2.56	B.
May	3,550	1,430	2,010	1.97	2.27	B.
June	4,860	930	2,160	2.12	2.36	B.
July	1,560	620	921	.903	1.04	B.
August	651	328	493	.483	.56	B.
September	6,690	240	1,210	1.19	1.33	B.
October	16,100	1,320	3,700	3.63	4.18	B.
November	11,200	2,200	4,950	4.85	5.41	B.
December	5,690	1,260	3,120	3.06	3.53	B.
The year	16,100	240	2,210	2.17	29.47	
1908.						
January	6,430	1,160	2,820	2.76	3.18	B.
February	12,600	1,160	2,860	2.80	3.02	B.
March	4,750	1,620	3,180	3.12	3.60	B.
April	4,640	1,830	2,790	2.74	3.06	B.
May	4,860	930	2,510	2.46	2.84	B.
June	1,830	478	958	.939	1.05	B.
July	1,210	328	687	.674	.78	B.
August	1,110	305	592	.580	.67	B.
September	505	130	310	.304	.34	B.
October	505	147	313	.307	.35	B.
November	452	130	290	.284	.32	B.
December	682	147	411	.403	.46	B.
The year	12,600	130	1,480	1.45	19.67	

[a] Discharge for 1906 is taken from U. S. Geol. Survey Water-Supply Paper 201, p. 114, 1907; discharge for 1907–8 from Water-Supply Paper 241, p. 172, 1910; and discharge for 1909 from Water-Supply Paper 261, p. 170, 1911.

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Monthly discharge of Housatonic River at Gaylordsville, Conn., for 1906–1909—Contd.

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.		
1909.						
January	5,450	182	1,250	1.23	1.42	C.
February	10,400	.....	3,270	3.21	3.34	B.
March	6,180	1,620	2,710	2.66	3.07	B.
April	8,940	2,520	3,970	3.89	4.34	B.
May	4,520	1,620	2,490	2.44	2.81	B.
June	2,360	561	1,260	1.24	1.38	B.
July	1,060	305	518	.508	.59	B.
August	1,760	220	668	.655	.76	B.
September	1,160	83	469	.460	.51	B.
October	890	114	445	.436	.50	B.
November	505	83	387	.379	.42	B.
December	2,050	220	632	.620	.71	B.
The year	10,400	83	1,510	1.48	19.85	

NOTE.—In the last column B indicates that the mean monthly flow is probably accurate within 10 per cent, C, within 15 per cent. Figures for 1906 are rated good. Minimum figures are low on account of storage of water at power plant above the station. Mean discharge estimated because of ice as follows: Jan. 16 to 31, 1909, 819 second-feet; Feb. 1 to 5, 1909, 650 second-feet; Dec. 24 to 31, 1909, 375 second-feet.

Natural lakes of glacial origin constitute a picturesque feature of Salisbury. They have remarkably clear water and clean shores and are popular summer resorts. South of Lakeville, Wononskopomuc Lake and Wononpakook Lake occupy the central valley; the former is nearly circular and almost a mile in diameter; the latter is about a quarter of a mile wide and a mile long. The elevation of Wononskopomuc Lake is about 760 feet; the elevation of Wononpakook Lake, about 735 feet. These two lakes are separated by a ridge of glacial material three-eighths of a mile wide. At Chapinville, in the northern part of the valley, there are two similar but somewhat larger lakes known as Twin Lakes, which are 735 feet above sea level and are separated by a strip of lowland only a few yards wide and connected by a small brook. The larger of the two is nearly circular and about a mile and a half in diameter; the other is half a mile wide and 2 miles long. Riga Lake and South Pond, near the top of Mount Riga, at an elevation of 1,700 feet, also owe their origin to glaciation. Riga Lake is about half a mile in diameter and is about twice as large as South Pond.

Salisbury consists so largely of mountainous, woody, or swampy land that only about 15,200 acres, or two-fifths of its area, is under cultivation and only about 200 persons are engaged in agriculture. All the mountainous parts are forested.

WATER-BEARING FORMATIONS.

Bedrocks.—The two principal rock formations in Salisbury are the Berkshire schist and the Stockbridge limestone.[1] The distribution

[1] See Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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of these rocks is indicated by the topography. The Berkshire schist is much more resistant to erosion than the limestone, and therefore forms the mountainous parts of the town. The limestone constitutes the bedrock in the valley, but it is believed to underlie the mountains of harder rocks also, particularly those along the west border. Pockets of iron ore occur in the limestone near its contact with the overlying schist, and the mining of these deposits is one of the principal industries. The only mine now in operation is at Ore Hill, but iron was formerly mined on a large scale at Salisbury.

The schist is a dense rock but is traversed by joints, some of which are water bearing. However, the topography throughout the area underlain by schist is such that surface water affords a more practicable source of supply than ground water, and for this reason no attempt has been made in this town to obtain water from these rocks. The limestone also is a dense crystalline rock, but in many places it is readily soluble, as is indicated by the solution cavities along the west shore of Lake Wononpakook. Percolating waters have widened many of the joints, thereby affording free underground drainage (Pl. V, *B*, p. 21). For this reason water is not stored long in the limestone above the base levels of underground drainage. Most of the wells that have been drilled into this rock have failed to obtain a permanent supply of water.

Till.—Till, which consists of mixtures of clay, sand, gravel, and bowlders, covers the rock in the mountainous districts and in the southern part of the central valley and is the most widely distributed surface deposit in Salisbury. Its thickness varies according to the topography. It is very thin immediately surrounding the rock outcrops and becomes thicker near the bottoms of the slopes. On the higher elevations the till was deposited by melting ice, but on the valley walls the material was squeezed against the rocks by advancing tongues of ice and remains as a plaster in some places 100 feet thick. On the valley floors it was heaped up by floods from the ice front and from the mountain sides. One hundred feet of till is exposed in the abandoned mine at Salisbury. The occurrence of water in till is discussed on page 15.

Stratified drift.—Deposits of stratified drift not more than 25 feet thick are found in small areas in the northern part of the central valley near Twin Lakes, and a few small deposits that consist of sand and gravel and show fluviatile cross-bedding are exposed in ravines along the mountain sides at elevations of about 100 feet. The elevated deposits of stratified drift are drained rapidly and are therefore not likely to afford good wells, but the low-lying beds of sand and gravel may be expected to furnish good supplies of water.

Alluvium.—Deposits of alluvium are found on the lowlands along Moore Brook and smaller deposits along Salmon Creek. The flood

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plains along the west side of the Housatonic between Falls village and Canaan are also covered by alluvium. These deposits are thin and are not important in determining the position of wells.

SURFACE-WATER SUPPLIES.

Water power is developed at the outlet of Wononskopomuc Lake and on Salmon Creek at Lime rock. A dam at the outlet of Twin Lakes at Chapinville furnishes power intermittently. Two impounding reservoirs at the headwaters of Burton Brook furnish the public water supply of Lakeville and Salisbury.

There is large opportunity for the utilization of surface water. The lakes are capable of furnishing an almost unlimited quantity of good water and some of them are so situated that pumping would not be necessary. At present, however, the lakes in the valley are not protected against contamination.

GROUND-WATER SUPPLIES.

Shallow dug wells ranging in depth from 8 to 27 feet and averaging 15 feet furnish most of the private domestic supplies in Salisbury. The depth to water ranges from 4 to 25 feet and averages 11 feet but fluctuates with the rainfall, the fluctuation as determined for three wells being 4, 5, and 6 feet, respectively. All except one of the wells examined obtained water from till and only two of them were reported to have failed. The yields, as determined in three wells, were 3, 3½, and 8 gallons, respectively. The quantity of water used from 27 wells ranges from 10 to 60 gallons and averages 27 gallons a day.

Drilled wells in Salisbury have not been generally successful, although this method of procuring water has not been fully tested. Ten wells, ranging in depth from 28 to 500 feet and penetrating bedrock, have been drilled. Two of these wells failed to obtain water in the limestone, and were therefore abandoned. Four others penetrated the crystalline rocks but were abandoned because the quantity obtained was not adequate, although each of them furnished about 5 gallons a minute. The other four wells yielded 5, 12, 20, and 60 gallons a minute, and are at present drawn upon to the extent of about 30 gallons, 200 gallons, 500 gallons, and 5,000 gallons a day, respectively.

Springs are numerous on the hillsides in all parts of the town. Most of them yield very small quantities of water, but a great many of them are capable of furnishing supplies for households. Fourteen springs were examined whose yields range from a quarter of a gallon to 20 gallons per minute. Seven of these are used, the consumption ranging from 20 to 500 gallons per day and averaging 110 gallons.

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All are gravity springs and fluctuate to some extent, but only two of those examined fail during dry weather.

PUBLIC WATER SUPPLY.

The public water system of Lakeville and Salisbury, operated by the Lakeville Water Co., takes its water from two reservoirs, with a total capacity of 18,000 gallons, at the head of Burton Brook. About 2,000 people are served from this system and the quantity has always been adequate.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Salisbury is presented in the following tables:

Drilled wells in Salisbury.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
2	E. C. Eggleston		920	16?	10	910		
3	Edward Garrity		880	15	9	871	6	(a)
4			585	12	5	580		
5			580	12	5	575		8+
8			638	11	4.5	633.5		
9		Slope	800	14	12	788		
10	J. Conour	Slope	815		14	801		
11	John Lloyd	Slope	830	16	14	816		3
12		Slope	920	18	12.5	907.5		
13	P. F. Cleveland	Hill	900	15	10	890		
14		Hill	920	12.5	7	913		
16	C. H. Bissel	Hill	800	22	9	881		
17	E. E. Burch	Slope	880	14	7.5	872.5		
18	Mike Walsh	Slope	700	12	12	688	4	Dry.
22	F. B. White	Hill	860	23	21	839		
23		Plain	800	12	8	792		3.5
25	Hotchkiss School	Hill	820	10	7	813		
26	Henry Wells	Hill	940	16	11	929		
27		Valley	760	9	8	752		
28	Peter Garrity	Hill	920	25	12	908	5	
32	D. T. Warner	Hill	1,770	27	25	1,745		
34		Flat	700	13.5	11	689		
36		Flat	780	8	6	774		
37	J. King	Flat	770	24.5	21.5	748.5		
44		Slope	810	18	10	800		
45		Slope	720	11	10	710		
46		Slope	770	16	11	759		
47		Hill	860	23	14	846		
52		Hill	960	25.5	13	947		
53		Slope	800	21	17	783		
54		Hill	860	12	9	851		
55		Hill	860	13	13	847		
57		Hill	770	16	9	761		
58		Slope	680	16	12	768		
59		Flat	780		13	757		
61		Flat	680	12	9	671		
62		Flat	640	9	8	632		
63		Slope	680	10	8.5	671.5		
66		Flat	670	12	10	660		

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Drilled wells in Salisbury—Continued.

Map No.	Owner.	Amount used per day.	Section.	Well.	Cover.
		Gallons.			
2	E. C. Eggleston	50	Till		Plank.
3	Edward Garrity	50	Till	Stone	Open.
4		25	Till	Stone	Plank.
5		40	Alluvium	Stone	Plank.
8		30	Till	Stone	Plank.
9		0	Till	Stone	Open.
10	J. Conour	50	Till	Stone	Plank.
11	John Lloyd	30	Till	Stone	Plank.
12		20	Till	Stone	Open.
13	P. F. Cleveland	35	Till	Stone	Plank.
14			Till	Stone	Open.
16	C. H. Bissel	60	Till	Stone	Plank.
17	E. E. Burch	15	Till	Stone	Plank.
18	Mike Walsh	0	Till	Stone	Open.
22	F. B. White	30	Till	Stone	Plank.
23		10	Till		Plank.
25	Hotchkiss School	15	Till	Stone	Shed.
26	Henry Wells	0	Till		Plank.
27		10	Till	Stone	Open.
28	Peter Garrity	20	Till	Stone	Open.
32	D. T. Warner	10	Till	Stone	Plank.
34		10	Till	Stone	Open.
36		10	Till	Stone	Open.
37	J. King	15	Till	Stone	Plank.
44			Till		
45		0	Till	Stone	Open.
46			Till		
47		10	Till		Plank.
52		50	Till	Stone	Plank.
53			Till	Stone	Plank.
54			Till		Plank.
55		10	Till	Stone	Plank.
57		20	Till		Plank.
58			Till		
59			Till		Plank.
61		20	Till	Stone	Open.
62		15	Till	Stone	Shed.
63			Till	Stone	Open.
66		20	Till	Stone	Open.

[a] Well goes dry.

Drilled wells in Salisbury.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Section.	Pump.	Diameter.
			Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*			*Inches.*
19	Mike Walsh	Hill	735	34	0	0	(?)			
21	Joseph Parsons	Slope	845	250	[a] 12	200	22	([b])		5
24	W. R. Warner	Hill	920	60	0	0	40			4
38	J. F. Fisher	Flat	750	500	5	0	0	Limestone	None.	4
39	do	Flat	538	500	5	0	0	Limestone	None	
41	do	Slope	950	200	4.5	0	0	Schist	None	
42	do	Slope	800	150	4	0	0	Schist	None	
43	Beal	Flat	760	200	5	30	(?)			
51	Salisbury School	Slope	940	[c] 215	60	5,000	8			6
56	Bierce	Valley	750	28	20	500	8	Limestone		4

[a] Flows 1 gallon per minute; used only in summer.

[b] Log:

	Feet.
Till	18
Limestone	145
Schist	87

[c] Well drilled in 1901; cost $3.75 per foot.

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Springs in Salisbury.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Amount used per day.	Temperature.	Improvements.
			Feet.	*Gallons.*	*Gallons.*	°*F.*	
6	.....	Slope....	650	0.25	.....	59	Horse trough.
7	.....	Slope...	600	4.5	.....	55	Do.
15	.....	Slope...	820	Slight.	.....	57	Do.
20	Mike Walsh.....	Slope...	870	1	20	55	
29	.....	Slope...	945	0.5	0	59	
30	D. T. Warner.....	Slope...	1,200	1	30	57	
31	Pettee.....	Valley..	1,090	[a] 20	50	48	
33	.....	Slope...	1,300	2	0	56	
35	Bushnell.....	Slope...	920	2	50	58	
40	Henry Schoville.....	Swamp.	760	20	500	50	
48	.....	Slope...	740	5	.....	57	
49	Little.....	Flat.....	960	6	20	56	
60	.....	Slope...	770	7	100	56	Concrete reservoir.
64	.....	Slope...	775	[b] 0.5	0	57	
65	.....	Slope...	640	[b] 1	0	56	

[a] No variation in yield. [b] Well goes dry.

QUALITY OF GROUND WATER.

Two Salisbury waters, analyses of which are given below, are moderate in mineral content, distinctly hard, calcium carbonate in type, and low in their contents of sulphate and chlorine.

Analyses of water from drilled wells in Salisbury.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2
Total solids at 180° C.	319	325
Total hardness as $CaCO_3$	160	245
Iron (Fe)	.7	Tr.
Carbonate radicle (CO_3)	Tr.	Tr.
Bicarbonate radicle (HCO_3)	360	313
Sulphate radicle (SO_4)	21	32
Chlorine (Cl)	1.1	5.4

1. Well of Joseph Parsons (Pl. XI, No. 21), 250 feet deep; sample collected June 25, 1915.
2. Well of Mr. Bierce (Pl. XI, No. 56), 28 feet deep; sample collected June 25, 1915.

NORTH CANAAN.

POPULATION AND INDUSTRIES.

North Canaan is in Litchfield County, in the northwest corner of Connecticut. It is reached by the Berkshire division of the New York, New Haven & Hartford Railroad (station at Canaan), by the Central New England Railway (stations at Canaan and East Canaan), and by daily stage from Southfield, Mass., via Mill River and Clayton, and by trolley from Sheffield, Mass. There are post offices at Canaan and East Canaan.

The town has an area of 19 square miles. It was separated from the town of Canaan and incorporated in May, 1858. The village of Canaan is in the town of North Canaan.

The population of North Canaan in 1910 was 2,171. The following table shows the population from 1870 to 1910, inclusive:

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Population of North Canaan, 1870 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1870	1,695	.....	.....	1900	1,803	7	.....
1880	1,537	.....	9	1910	2,171	20	.....
1890	1,683	10	.....				

The principal industries are agriculture, the manufacture of pig iron and lime, and the quarrying of marble and quartzite.

TOPOGRAPHY.

The region east of the village of Canaan is mountainous. Rattlesnake Hill, which lies between Canaan and Sodom, 1,000 feet above sea level, or 340 feet above Housatonic River, is produced by outcrops of limestone and quartzite. The foothills of Ball Mountain, between Sodom and the east border of the town, attain an elevation along the east boundary of 1,300 feet. Canaan Mountain rises on the south side of Blackberry River to an elevation of 1,927 feet a short distance south of the south boundary. A low range of limestone hills extends along the west border of the town from the latitude of Canaan to the south line. The highest point in these hills is 800 feet above sea level. Between these hills and Canaan Mountain and between Rattlesnake Hill and Housatonic River there is a flat plain about a mile wide and 680 feet above sea level, which was formerly the bed of the Housatonic. (See Pl. XI, in pocket.)

The Housatonic forms the west boundary of North Canaan and receives as tributaries all the minor streams of the town. Konkapot River enters the town of Clayton, follows around the north foot of Rattlesnake Hill, crosses the State line, and enters the Housatonic west of Ashley Falls, Mass. Blackberry River, which drains nearly the entire town, flows across the town along the north foot of Canaan Mountain and enters the Housatonic west of Canaan. Whiting River flows southward through Canaan Valley to East Canaan, where it joins Blackberry River. A small amount of power is developed on Blackberry River at Canaan.

The woodlands in North Canaan are confined to the hilltops and comprise an area of only about 5 square miles. The remainder of the town is devoted to agriculture, about half being tilled land and the rest meadows.

WATER-BEARING FORMATIONS.

Bedrocks.—Most of the rock floor of North Canaan is composed of Stockbridge limestone, but an area in the northeast corner of the town, north of Blackberry River and east of Whiting River, is underlain by Becket gneiss. Canaan Mountain consists of Berkshire schist, and in Rattlesnake Hill and at the Central New England Railway

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bridge over Whiting River the Cheshire ("Poughquag") quartzite[1] comes to the surface. All of these rocks outcrop in many places and the limestone and quartzite are quarried. (See p. 20.)

Till.—Unstratified glacial deposits cover the rock on Canaan Mountain and Rattlesnake Hill and on the hills in the northeast quarter of the town. They range in thickness from a few inches surrounding the rock exposures to 25 or 30 feet. (See p. 15.)

Stratified drift.—In the lowlands along Housatonic and Blackberry rivers bedrock is covered with stratified sand and gravel. These deposits form a terrace bordering the hills near the mouth of Blackberry River and a much broader terrace extending from Canaan northward along the base of Rattlesnake Hill. Similar deposits occur along Squabble Brook north of Sodom. The stratified deposits range in thickness from a few feet to about 50 feet, the thickest deposits being just west of Canaan. The water-bearing capacity of these deposits is large, and by means of dug or driven wells water suitable for domestic use or for additions to public supplies is available.

Infiltration galleries (p. 42) in the stratified deposits in the central and west parts of the town would probably afford rather large quantities of water, and this method of utilization should receive consideration in connection with proposed public supplies.

GROUND-WATER SUPPLIES.

The average depth of 16 dug wells is 14 feet and the depth to water ranges from 5 to 19 feet and averages 11 feet. The fluctuation of the water table was reported for three wells to be 4, 7, and 8 feet, respectively. All the wells examined end in till and only two fail in dry weather. The quantity of water used daily, as reported for 10 wells, ranges from 10 to 40 gallons and averages 21 gallons.

A drilled well, 333 feet deep, in the village of Canaan (see No. 23, Pl. XI), at an elevation of 670 feet, was sunk at a cost of $1,800, for the purpose of obtaining a supplementary supply for the public waterworks. It yielded, however, only 17 gallons a minute, and as this quantity was considered inadequate it was abandoned, a larger supply being obtained by sinking a shallow well into the drift.

Springs are common on the hillsides, but all of them yield small quantities of water and most of them are intermittent. The average yield of the permanent springs is about a gallon a minute. The yield of the springs is, however, generally much greater than the amount used, which averages only about 35 gallons a day.

PUBLIC WATER SUPPLY.

The water supply for the village of Canaan is obtained from a 3,000,000-gallon reservoir on the north slope of Canaan Mountain.

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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The reservoir is fed by springs which have a combined yield of 55,000 gallons a day. All the water is used for domestic needs, and about 1,000 persons are supplied. The consumption in summer is 65,000 gallons a day. In dry summers, when the supply is inadequate, additional water is obtained from a dug well 12 feet square and 12 feet deep, lined with planking. The water in this well is usually 6 feet deep, but pumping at the rate of 110 gallons a minute lowers it nearly to the bottom.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of North Canaan is presented in the following tables:

Dug wells in North Canaan.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	.....	.....	700	10	10	690	.....
2	H. R. Cadwell	Flat	720	[a] 17	16	704	7
3	R. D. Miller	Flat	715	11	10	705	.....
4	T. P. Couch	Flat	720	10	7	713	.....
6	E. P. Adsit	Slope	700	12	10	690	.....
7	.....	Slope	880	.....	9	871	.....
8	.....	Flat	860	16	11	849	.....
11	E. Taylor	Hill	855	12	10	845	.....
12	Rogers	Flat	818	10	8	810	.....
13	Langdon	Flat	810	10	5	805	.....
14	.....	Flat	822	14	8	814	.....
15	Thomas Morris	Flat	815	16	.....	.....	4
17	.....	Flat	765	18(?)	15(?)	750(?)	.....
18	.....	Slope	780	22	19	761	.....
19	.....	Hill	815	19	12	803	.....
21	George Preny	Hill	850	23	19	831	8
22	Canaan Water Co.	Flat	680	12	6	674	.....

Map No.	Owner.	Amount used per day.	Section.	Wall.	Cover.
		Gallons.			
1	.....	30	Till	Stone	Open.
2	H. R. Cadwell	([b])	Till	Stone	Loose boards.
3	R. D. Miller	20	Till	Stone	Shed.
4	T. P. Couch	.....	Till	Stone	Plank.
6	E. P. Adsit	.....	Till	Stone	Plank.
7	.....	.....	Till	Stone	Open.
8	.....	0	Till	Stone	Lattice shed.
11	E. Taylor	20	Till	.....	
12	Rogers	25	Till	.....	
13	Langdon	15	Till	Stone	Open.
14	.....	10	Till	Stone	Open.
15	Thomas Morris	[c] 10	Till	Stone	Plank.
17	.....	20	Till	Stone	Plank.
18	.....	20	Till	Stone	Plank.
19	.....	40	Till	Stone	Lattice shed.
21	George Preny	10	Till	Stone	Plank.
22	Canaan Water Co.	.....	Till	Plank	Shed.

[a] Tile at bottom, 2 feet. [b] Well goes dry. [c] Dry.

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Springs in North Canaan.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Amount used per day.
			Feet.	*Gallons.*	*Gallons.*
5	.....	Slope....	735	4	30
9	.....	Slope....	980	0.25	20
10	.....	Slope....	1,120	0.5	.....
16	Thomas Morris.....	Slope....	845	1	60
24	.....	Slope....	755	1.5	.....

CANAAN.

POPULATION AND INDUSTRIES.

Canaan, in Litchfield County, in the northwest corner of Connecticut, is reached by the Berkshire division of the New York, New Haven & Hartford Railroad, which has stations at Falls Village and Lime rock; by mail carrier from Cornwall Hollow through South Canaan and Huntsville daily, and also over Barrack Mountain by Lime rock station, part of Lime rock village, and Amesville daily. Post offices are maintained at Falls Village and during the summer at Pine Grove. The rural free delivery reaches outlying parts of the town.

Canaan was incorporated in October. 1739. The area of the town is 33 square miles.

The population in 1910 was 702. The population from 1756 tc 1910, inclusive, is shown in the following table. The chief industry is agriculture.

Population of Canaan, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756.....	1,100	.....	.....	1840.....	2,166	.....	6
1774.....	1,635	48	.....	1850.....	2,627	21	.....
1782.....	2,061	26	.....	1860.....	2,834	8	.....
1790.....	.....	.....	.....	1870.....	1,257	.....	[a]55
1800.....	2,137	.....	.....	1880.....	1,157	.....	8
1810.....	2,203	3	.....	1890.....	970	.....	16
1820.....	2,332	6	.....	1900.....	820	.....	16
1830.....	2,301	.....	1	1910.....	702	.....	14

[a] North Canaan was set off from Canaan in 1858.

TOPOGRAPHY.

The topography of Canaan is produced by faulting and by erosion. Canaan Mountain occupies the northeast corner of the town, and Barrack Mountain and Titus Mountain occupy the south half. Lowlands, which were at one time flood plains of Housatonic River, extend from Lime rock station northward to the town line and from Housatonic River eastward to South Canaan and the base of Canaan

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Mountain. The general elevation of these lowlands is about 680 feet above sea level. The highest elevation in the town is Bradford Mountain, the principal peak on Canaan Mountain, which is 1,927 feet above sea level. The altitude of Barrack Mountain is 1,140 feet, of Cobble Hill 1,278 feet, and of two peaks which form the northern part of Titus Mountain 1,420 and 1,450 feet, respectively. (See Pl. XI, in pocket.)

Housatonic River forms the west boundary of Canaan and receives all the drainage from the town; its principal tributary is Hollenbeck River. The south branch or main stream of Hollenbeck River rises in the hills east of Huntsville, flows through a narrow valley between Cobble Hill and Beebe Hill, passes through South Canaan, and enters the Housatonic 1 mile north of Falls Village. The east branch of Hollenbeck River rises in Wangum Lake, near the top of Canaan Mountain, at an elevation of 1,410 feet, and flows between Cobble Hill and Canaan Mountain to its confluence with Hollenbeck River half a mile north of South Canaan. The north branch of this river rises near the town line at the foot of Canaan Mountain and flows due south till it joins Hollenbeck River. The lowlands between Canaan Mountain and Housatonic River are poorly drained and are marshy throughout the greater part of the year.

The mountainous parts of Canaan, comprising an area of about 25 square miles, are forested. The cultivated lands are confined to the valleys in the immediate vicinity of South Canaan.

WATER-BEARING FORMATIONS.

Bedrocks.—Berkshire schist and Becket gneiss [1] constitute the rock floor in the mountainous parts of the town. The Cheshire ("Poughquag") quartzite appears at the surface in Cobble Hill and at several places south of Hollenbeck River. All the lowland area is underlain by Stockbridge limestone. The steep slopes in the southern and western parts of the town afford numerous rock exposures, but the limestone appears at the surface only in the low hills adjacent to Housatonic River. The occurrence of water in rocks of this kind is discussed on page 20.

Till.—The rocks throughout the eastern and southern parts of the town at elevations of more than 700 feet above sea level are covered with mixtures of bowlders, sand, and clay, ranging in thickness from a few inches to 25 or 30 feet. (See p. 15.)

Stratified drift.—Stratified deposits of sand and gravel occur generally at elevations less than 700 feet. The thickest deposits are in the valley just west of Canaan Mountain and in the immediate vicinity of South Canaan, where they are in some places more than 30 feet deep.

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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These deposits afford an opportunity for obtaining ground-water supplies by means of dug and driven wells. (See p. 38.)

SURFACE-WATER SUPPLIES.

Opportunity for the development of power is afforded by the south and east branches of Hollenbeck River. Water supply of moderate size for public use may be obtained from Wangum Lake or by constructing impounding reservoirs at a number of points along the south slope of Canaan Mountain and along the south border of the town.

GROUND-WATER SUPPLIES.

The average depth of shallow wells is 16 feet and the maximum depth about 23 feet, but water is obtained within 10 feet of the surface on the lowlands north of South Canaan. The depths to water range from 5 to 20 feet and average about 12 feet. The fluctuation of the water table was observed in two wells to be 5 and 6 feet, respectively. The yield of one well was estimated at about 3 gallons a minute. The quantity of water used daily from two wells was reported as 10 and 15 gallons. Six of the wells examined end in till and two in alluvium. Two of the wells which end in till fail during dry weather.

There are four drilled wells in Canaan, ranging in depth from 42 to 90 feet and averaging about 62 feet. The yields obtained from three of these wells were 1½ gallons, 2 gallons, and 3 gallons, respectively.

Springs yielding from half a gallon a minute to 6 gallons a minute and averaging about 2 gallons a minute are numerous on the slopes throughout the town. All are gravity springs, and most of them are intermittent. Four of the springs examined are used for private supplies, the average consumption being about 47 gallons a day.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Canaan is presented in the following tables:

Dug wells in Canaan.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
1	.....	Flat.....	685	10	5	680	.....	.....
2	.....	Slope....	720	20	20	700	.....	Dry.
4	.....	Slope....	715	23	19	696	.....	.....
7	H. Scoville.....	Flat.....	875	14	6	869	6	½
10	.....	Flat.....	690	10	10	680	.....	.....
11	.....	Hill.....	935	22	18	917	.....	.....
17	D. Brinton.....	Flat.....	680	.....	11	669	.....	.....
18	W. J. Russell.....	Flat.....	680	11	10	670	5	(a)

a Well goes dry.

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Dug wells in Canaan—Continued.

Map No.	Owner.	Amount used per day.	Section.	Wall.	Cover.
		Gallons.			
1	.....	.....	Alluvium...	Stone.....	Open.
2	.....	0	Till.....	Stone.....	Plank.
4	.....	.....	Till.....	.....	Plank.
7	H. Scoville.....	10	Alluvium...	Stone.....	Plank.
10	.....	.....	Till.....	Stone.....	Plank.
11	.....	0	Till.....	Stone.....	Open.
17	D. Brinton.....	.....	Till.....	Stone.....	Plank.
18	W. J. Russell.....	15	Till.....	Stone.....	Plank.

Drilled wells in Canaan.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Section.	Diameter.	Quality of water.
			Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*		*Inches.*	
15	G. Schultis....	Slope....	600	90	1.5	0	0	Limestone..	.....	Rusty.
16	L. J. Morris...	Hill.....	580	72	2	.....	0	Limestone..	.....	
19	J. M. Benjamine.	Hill.....	585	42	3	.....	8	Limestone..	4	
20	.....do.....	Hill.....	585	43	.....	.....	19	Schist.....	.....	

Springs in Canaan.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Amount used per day.	Temperature.
			Feet.	*Gallons.*	*Gallons.*	° *F.*
3	.....	Slope....	775	6	100	.....
5	.....	Slope....	800	0.5	40	55
6	M. C. Dean.....	Slope....	930	1	.....	54
8	Lucas.....	Slope....	800	1	30	51
9	E. S. Parker.....	Valley..	750	1	20	53
12	.....	Valley..	905	3	.....	54
13	.....	Slope....	868	2.5	.....	.....
14	.....	Slope....	740	2	.....	54

WINDHAM.

POPULATION AND INDUSTRIES.

The town of Windham is in the southwestern corner of Windham County, in the east-central part of the State. It is reached by the Highland division of the New York, New Haven & Hartford Railroad (stations at Willimantic, North Windham, and South Windham) by the New London Northern Railroad (stations at Willimantic and South Windham); by electric railway from Baltic, Norwich, and New London; and by stage from Ashford, Warrenville, Mount Hope, and Mansfield Center. Post offices are maintained at Willimantic, Windham, North Windham, and South Windham, and outlying parts of the town are reached by rural free delivery.

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Windham was incorporated in May, 1692. Its area is 26 square miles.

The population of the town of Windham in 1910 was 12,604; of the city of Willimantic, 11,230. The following table shows the population of the town from 1756 to 1910, inclusive.

Population of Windham, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	2,446			1840	3,382	20	
1774	3,528	44		1850	4,503	33	
1782	3,571	1		1860	4,711	5	
1790	2,765		23	1870	5,412	15	
1800	2,644		4	1880	8,264	53	
1810	2,416		9	1890	10,032	21	
1820	2,489	3		1900	10,137	1	
1830	2,812	13		1910	12,604	24	

Water power has been developed on a large scale at Willimantic by means of dams built across Willimantic River. Most of these structures are owned by the American Thread Co.

The principal industries in Windham are manufacturing and agriculture. The principal manufactured products are spool cotton, silk twist, silk and cotton fabrics, carriages, and silk-making, paper-making, and other machinery.

TOPOGRAPHY.

The average elevation of Windham is 400 feet above sea level. The highest elevation, 661 feet, is on Obwebetuck Hill; the lowest, 100 feet, is in the southeastern corner of the town. Blake Hill, Prospect Hill, and Obwebetuck Hill, between the Shetucket and the western boundary of the town, are produced by undulation of the rock surface. The hills in the eastern half of the town are also rock hills, but between Windham Center and Willimantic the topography is due to valley filling. (See Pl. XII, in pocket.)

The principal stream is Shetucket River, which is produced by the confluence of the Willimantic and Nachaug at Willimantic.

About one-half of the area of Windham is forested and about one-fourth is under cultivation, the rest of the town being occupied by the city of Willimantic. Most of the farm lands are situated on the plain that lies between Willimantic and Windham Center and extends southward along the river to the Franklin boundary.

WATER-BEARING FORMATIONS.

Bedrocks.—The rock floor of Windham consists of gneisses and schists of unknown age, which have been classified according to their lithologic characters. The western half of the town is underlain by

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rocks which in the publications of the Connecticut State Geological and Natural History Survey have been designated the Willimantic gneiss, and the eastern half by rocks which have been designated Scotland schist, Hebron gneiss, and Eastford granite gneiss.[1] These rocks are exposed in many places along the eastern, southern, and western borders, but in the central and northern parts of the town they are covered by glacial deposits. All these rocks contain joints, the largest of which extend to depths of 200 or 300 feet and yield small quantities of water (p. 20).

Till.—At elevations of more than 300 feet above sea level the rock is covered with unstratified drift, the average thickness of which is about 25 feet. (See p. 15.)

Stratified drift.—Stratified deposits consisting of gravel and some sand are found in most places where the surface is less than 300 feet above sea level. Some of the sections along the west side of Shetucket River near South Windham reveal thicknesses of 25 feet. These deposits constitute the most important water-bearing formation in Windham (p. 40).

GROUND-WATER SUPPLIES.

Seventeen dug wells in Windham range in depth from 12 to 26 feet and average about 15 feet. Depth to water ranges from 2 to 21 feet and averages about 13 feet. The fluctuation of the water table in one well was 10 feet, and one well yielded 5 gallons a minute. The quantity of water used, reported for four wells, ranged in amount from 20 to 40 gallons a day. Three other wells are not used at all. Only one of the wells examined in this town is known to fail in dry seasons.

The well of the Willimantic Bottling Co. (No. 22, Pl. XII), which is the only drilled well in Windham, is 178 feet deep, the lowest 163 feet being in rock. Its elevation is 270 feet above sea level. It is used only occasionally to supply drinking water, the quantity used being about 20 gallons a day.

Springs are common along the slopes west of Shetucket River and on the hillsides in the eastern part of the town. All are gravity springs, averaging in yield between 1 and 2 gallons a minute. At a few places in the vicinity of Windham Center small springs occur in groups and, being properly developed, yield very desirable supplies. The quantity of water used from one of these groups exceeds 1,200 gallons a day.

The stratified sands and gravels of Windham contain large quantities of ground water. Driven wells drawing from these deposits would probably yield sufficient water to meet the needs of the villages in this town, and it is possible that Willimantic could obtain

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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water in this manner should the present supply become inadequate. Infiltration galleries (p. 42) in the stratified deposits along Willimantic River would afford large quantities, and should receive consideration in connection with proposed public systems.

PUBLIC WATER SUPPLY.

The waterworks of Willimantic are owned by the city. The water is pumped from Willimantic River at a dam 2 miles north of the city to a reservoir that will hold 5,000,000 gallons. About 12,000 people are served with 600,000 to 900,000 gallons a day. Meters are exclusively used. The water is considered good, and no shortage has been reported.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Windham is presented in the following tables:

Dug wells in Windham.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
1		Slope	275	20	14	261		
2		Slope	300	12	9	291		
3	A. Lewis	Plain	285	21	15	270		
4		Plain	265	26	19	246		
5		Plain	265	22	21	244		(a)
6		Slope	318	16	14	304		
7		Slope	300		14	286		
9	Brookman	Slope	365	15	14	351		
10		Plain	490	18	16	474		
11		Plain	310	16.5	15	295		
12	Thompson	Plain	300	18	16	284		5
13		Plain	350		2	348		
15		Slope	285		12	273		
16	Gould	Hill	325	16	13	312		
17		Plain	265	12	7	258		
19	Wilson	Slope	230	17	12	218	10	
20	W. E. Light	Hill	225	18	14	211		
24		Plain	280					

Map No.	Owner.	Amount used per day.	Depth to rock.	Section.	Wall.	Cover.
		Gallons.	*Feet.*			
1		20		Till	Stove	Plank.
2		0		Till	Stone	Open.
3	A. Lewis	0		Till	Stone	Open.
4				Till	Stone	Shed.
5		30		Gravel	Stone	Open.
6				Till	Stone	Open.
7				Till		Plank.
9	Brookman		15	Till	Stone	Plank.
10				Till	Stone	Open.
11				Till	Stone	Open.
12	Thompson	25		Till	Stone	Plank.
13		0		Till		None.
15				Till	Stone	Open.
16	Gould			Till	Stone	Open.
17				Till	Stone	Open.
19	Wilson	40		Till		Open.
20	W. E. Light			Sand and gravel.	Stone	Plank.
24						

a Well goes dry.

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Springs in Windham.

Map No.	Owner.	Topographic position.	Yield per minute.	Amount used per day.	Temperature.	Improvements.
			Gallons.	*Gallons.*	°*F.*	
8	.....	Slope...	.....	.....	55	Horse trough.
14	.....	Slope...	.....	0	55	
18	.....	Valley..	1	0	56	
21	Windham Aqueduct Co.....	Slope...	.....	1,200+	55	14 families supplied.

QUALITY OF GROUND WATER.

The Willimantic Bottling Co.'s well yields moderately mineralized, rather hard water that would probably form hard scale in boilers because of its content of sulphate. It contains only a trace of iron.

Analysis of water of the 178-foot drilled well of the Willimantic Bottling Co. (Pl. XII, No. 22), collected June 15, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	228
Total hardness as $CaCO_3$	103
Silica (SiO_2)	37
Iron (Fe)	Tr.
Calcium (Ca)	23
Carbonate radicle (CO_3)	4.5
Bicarbonate radicle (HCO_3)	75
Sulphate radicle (SO_4)	69
Chlorine (Cl)	5.4

FRANKLIN.

POPULATION AND INDUSTRIES.

Franklin is in the north-central part of New London County, in the east-central part of the State. It is reached by the New London Northern Railroad, which has stations at Franklin, North Franklin, and Yantic (just over the south line of the town), and by electric railway from Willimantic, Baltic, Norwich, and New London. Post offices are at Yantic and North Franklin. Rural free delivery reaches all parts of the town.

Franklin was taken from Norwich and incorporated in May, 1786. The area of the town is 20 square miles.

The population of Franklin in 1910 was 527. The population from 1800 to 1910, inclusive, is shown in the following table. The principal industry is agriculture.

Population of Franklin, 1800 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1800	1,210	.....	.....	1860	2,358	163	.....
1810	1,161	.....	4	1870	731	.....	69
1820	1,161	.....	.....	1880	686	.....	6
1830	1,194	3	.....	1890	585	.....	15
1840	1,000	.....	16	1900	546	.....	6
1850	895	.....	11	1910	527	.....	3

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TOPOGRAPHY.

The present topography has been produced by the dissection of a peneplain and the subsequent filling of the valleys with glacial deposits. The highest elevations in Franklin are the summits of the nine hills, including Prospect Hill, Avery Hill, Hearthstone Hill, and Blue Hill, which embrace nearly the entire area of the town. The hills have a uniform height of about 520 feet above sea level. The valleys have been filled to some extent with glacial drift, which forms flat valley floors standing about 180 feet above sea level.

The accumulations of drift in the valleys have interrupted drainage, and considerable areas are therefore swampy. Four brooks in the northern part of Franklin empty into a swamp just east of Avery Hill, and Beaver Brook, a tributary to Shetucket River, rises in this swamp. Similar areas lie along Susquetonscut Brook, a tributary to Yantic River. Beaver Brook and Susquetonscut Brook carry nearly all of the drainage in Franklin, but a small amount enters Shetucket River directly.

About half the area of Franklin is forested, including most of the slopes and considerable areas in the low swampy lands in the central and western parts of the town. The remaining half is nearly all under cultivation.

WATER-BEARING FORMATIONS.

Bedrocks.—The town of Franklin is underlain by crystalline rocks which in publications of the Connecticut State Geological and Natural History Survey have been designated the Scotland schist, the Hebron gneiss, the Canterbury granite gneiss, and the Pomfret phyllite.[1] These rocks are exposed in many places throughout the town (Pl. XII, in pocket). All are broken by joints, or cracks, the largest of which probably extend 200 or 300 feet below the surface and are capable of furnishing moderate supplies of water. (See p. 20.)

Till.—Unstratified deposits of bowlders, gravel, sand, and clay cover the rock in most places. The extent of these deposits is indicated by the distribution of bowlders on the surface of the ground. Their thickness ranges from a few inches to 30 feet and averages about 15 feet. The deepest deposits are at the bases of the slopes and the thinnest on the tops of the hills, where the rocks are barely covered. The occurrence of water in till is discussed on page 15.

Stratified drift.—Kamelike deposits of stratified drift are found in the valley in the central part of the town between Hearthstone Hill and Franklin and between Hearthstone and Pautipaug Hill. Although these deposits are small in extent and probably not very thick, they are nevertheless important sources of ground water for domestic use.

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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GROUND-WATER SUPPLIES.

Dug wells in Franklin range in depth from 8 to 32 feet and average 18 feet. Depth to water ranges from 5 to 29 feet and averages about 15 feet. The fluctuation of the water table ranges from 5 to 20 feet and averages about 10 feet. Nearly all the wells end in till and most of them are situated on slopes where the drift is thin and the ground-water supply therefore small. About 30 per cent of the shallow wells in the town go dry. The quantity of water used, as reported for six wells, ranges from 10 to 40 gallons per day and averages about 30 gallons.

Two wells have been drilled to depths of 125 feet and 235 feet, respectively. One of these wells is not used because of the high iron content of its water. From the other well about 50 gallons per day is used. Neither well is suitable for domestic supply on account of the iron in the water. Both wells end in crystalline rocks, from which the iron is derived.

Gravity springs, many of which are intermittent, issue on the numerous slopes throughout the town and range in yield from very small amounts to about 6 gallons a minute. The largest springs are at low levels and the water which they furnish must therefore be carried or pumped.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Franklin is presented in the following tables:

Dug wells in Franklin.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
1	.....	Hill.....	310	(?)11	10	300	.....	.....
2	.....	Slope...	275	13	10	265	.....	.....
4	.....	Hill.....	470	(?)16	15	455	.....	.....
5	.....	Hill.....	435	12	10	425	.....	.....
6	M. F. Rodman.....	Plain...	190	.....	10	180	.....	.....
7	.....	Slope...	150	8	7	143	.....	.....
8	Mabry.....	Slope...	185	32	29	158	.....	.....
10	.....	Slope...	210	24	15	195	20	.....
11	.....	Plain...	200	.....	11	189	.....	.....
12	S. G. Hartshorn.....	Slope...	185	15	5	180	.....	2.5
15	T. O'Hearn.....	Plain...	180	(?)25	23	157	.....	.....
16	.....	Slope...	160	20	20	140	5	(a)
17	.....	Plain...	150	18	16	134	7	.....
18	F. S. Barber.....	Plain...	175	20	16	159	.....	.....
19	.....	Plain...	175	18	16	159	.....	.....
20	John Howe.....	Slope...	200	14	12	188	.....	(a)
21	School.....	Slope...	300	10	.....	.....	.....	(a)
22	.....	Slope...	355	14	12	343	.....	.....
23	.....	Hill.....	480	13	.....	.....	.....	(a)
25	G. L. Ladd.....	Hill.....	510	17	16.5	493.5	6	(a)
27	E. Mitchell.....	Hill.....	285	28	23	262	.....	.....
28	Town hall.....	Hill.....	380	27	25	355	.....	(a)
29	.....	Slope...	240	.....	12	228	.....	.....
31	M. H. Race.....	Hill.....	315	.....	11	304	.....	(a)
32	.....	Slope...	295	.....	10	285	.....	.....

a Well goes dry.

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Dug wells in Franklin—Continued.

Map No.	Owner.	Amount used per day.	Depth to rock.	Section.	Wall.	Cover.
		Gallons.	*Feet.*			
1		35		Till		Plank.
2				Till	Stone	Plank.
4				Till		Plank.
5		0	11	Till	Stone	Open.
6	M. F. Rodman			Till	Stone	Open.
7				Till	Stone	Open.
8	Mabry			Till	Stone	Open.
10		0		Till	Stone	Open.
11		20		Till	Stone	Plank.
12	S. G. Hartshorn	60		Till	Stone	Shed.
15	T. O'Hearn			Till	Stone	Open.
16		0	20	Till	Stone	Open.
17		0		Till	Stone	Open.
18	F. S. Barber			Till	Stone	Open.
19				Till	Stone	Plank.
20	John Howe	10	14	Till	Stone	Plank.
21	School	0	10	Till	Stone	Plank.
22		20		Till	Stone	Open.
23		0	12	Till	Stone	Open.
25	G. L. Ladd	0	17	Till	Stone	Open.
27	E. Mitchell	40		Till	Stone	Open.
28	Town hall	0		Till	Stone	Plank.
29				Till	Stone	Plank.
31	M. H. Race			Till	Stone	Plank.
32		0		Till	Stone	Plank.

Drilled wells in Franklin.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Depth to rock.	Quality of water.	Drilled in year—
			Feet.	*Feet.*	*Gallons.*	*Gallons.*	*Feet.*		
3	Mrs. F. E. Johnson	Hill	460	125	26	50		Rusty	1911
24	Sherman Loomis	Hill	500	235		0	15	Rusty	1911

Springs in Franklin.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Amount used per day.	Temperature.
			Feet.	*Gallons.*	*Gallons.*	° *F.*
9		Slope	190	0.5	0	53
13		Slope	230	.2	0	55
14		Slope	230	.5	0	54
26		Slope	235	6	0	50
30	Woodward	Slope	260	1		

QUALITY OF GROUND WATER.

The shallow well of T. O'Hearn yields soft water of very low mineral content.

Analysis of water of the 25-foot (?) well of T. O'Hearn (Pl. XII, No. 15), collected June 15, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	46
Total hardness as $CaCO_3$	19
Iron (Fe)	.10
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	27
Sulphate radicle (SO_4)	3
Chlorine (Cl)	2.9

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SAYBROOK.

POPULATION AND INDUSTRIES.

Saybrook is in the south-central part of Connecticut, in Middlesex County. It is reached by the Valley branch of the New York, New Haven & Hartford Railroad (station at Deep River), and by steamboats from Hartford and New York daily during the open season. The post office is at Deep River. The western part of the town receives mail by rural delivery from Deep River.

Saybrook was settled in 1635 and united with Connecticut in December, 1644. The area of the town is 15 square miles.

The population of Saybrook in 1910 was 1,907. The population from 1756 to 1910 is shown in the following table:

Population of Saybrook, 1756 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1756	1,931	.....	.....	1840	3,417	.....	[a] 32
1774	2,687	39	.....	1850	2,904	.....	15
1782	2,738	2	.....	1860	1,213	.....	58
1790	3,233	18	.....	1870	1,267	4	.....
1800	3,363	4	.....	1880	1,362	8	.....
1810	3,996	19	.....	1890	1,484	9	.....
1820	4,165	4	.....	1900	1,634	10	.....
1830	5,018	20	.....	1910	1,907	17	.....

[a] Westbrook was set off from Saybrook in 1840.

The principal industries are agriculture and the manufacture of piano keys, piano-player actions, ivory and bone goods, wire goods, button hooks, crochet needles, etc.

Four dams on Deep River, in the vicinity of Deep River, furnish power.

TOPOGRAPHY.

The lowest elevation in Saybrook is sea level along Connecticut River; the highest is about 460 feet, in the northwest corner of the town. The rock cover is generally thin and the present topography is due chiefly to undulations of the rock floor.

Connecticut River forms the east boundary of Saybrook and receives all the drainage from the town. Deep River rises in the northwest corner of the town and enters the Connecticut at Deep River. The total fall of this stream is 400 feet, or an average of about 50 feet to the mile.

Half the area of Saybrook, including most of the hills and steep slopes, is wooded. The farm lands occupy the central part of the town about Winthrop and areas near the Connecticut south of Deep River.

WATER-BEARING FORMATIONS.

Bedrocks.—The bedrocks, which Gregory has named Mamacoke, Middletown, and Haddam gneisses and Haddam granite gneiss,[1]

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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appear at the surface on the hillsides throughout the town (Pl. XIII, in pocket). Joints or cracks appear in all exposures and range in size from partings that are barely visible to openings an inch or more in width. The largest extend 200 or 300 feet below the surface, affording space for the storage of ground water (p. 20).

Till.—Glacial drift forms a mantle over the rock surface throughout the greater part of the town and consists of typical till or unstratified sand and clay containing numerous bowlders. It ranges in thickness from a few inches to about 30 feet and averages about 20 feet. Many domestic water supplies are obtained from dug wells which end in till. (See p. 15.)

Stratified drift.—In the vicinity of Deep River the drift includes patches of sand which were deposited by water around the hills. These deposits are not, however, large enough to be of much importance in determining the location of wells.

GROUND-WATER SUPPLIES.

The average depth of shallow wells is about 12 feet. Eighteen wells examined ranged in depth from 8 to 18 feet. The depth to water, as determined by the measurement of 22 wells, ranges from 5 to 17 feet and averages about 10 feet. The total fluctuation of the water table in three wells was 3, 5, and 7 feet, respectively. Nearly all the wells in Saybrook are situated in till and afford adequate supplies. Only one well was reported to go dry. The quantity of water used daily, as reported for six wells, ranges from 10 to 30 gallons and averages 20 gallons.

Springs are common along the streams and on the slopes in Saybrook, but they are generally small, few yielding more than half a gallon per minute, and all responding to changes in the weather.

PUBLIC WATER SUPPLY.

Part of Deep River is supplied with water from a reservoir of the Guilford Chester Water Co., near Chester. A flat rate is charged and the quantity of water delivered is not measured.

RECORDS OF WELLS AND SPRINGS.

The available information concerning the wells and springs of Saybrook is presented in the following tables:

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Dug wells in Saybrook.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
1		Hill	160	14	14	146		
2		Plain	146	9	5	141		
3		Slope	200		11	189		
4		Valley	260	11	9	251		
5	L. T. Louis	Slope	300	13	13	287	5	
6		Plain	360	14	8	252		
7	Jacob Hemmig	Slope	390	12.5	10	380		
8		Slope	370	17	16	354		
9	J. M. Mook	Slope	290	9.5	8	282		4
10		Hill	290	10.5	9	28		
13		Slope	300	11	10	290		
14		Slope	300	9.5	8.5	291.5		
16		Slope	140	11	7	133		
17		Hill	140	9	6	134		
18		Hill	140	8	5	135		
20		Hill	140	10.5	6	134		(a)
22		Slope	20		8	12		
23		Slope	30	12	11.5	18.5	3	
24	R. C. Brockman	Hill	20	18.5	17	3		
25	E. E. Smith	Slope	40		15	25		
26	A. E. Lord	Slope	60		16	44		
27		Plain	155	12	10	145	7	

Map No.	Owner.	Amount used per day.	Section.	Wall.	Cover.
		Gallons.			
1		20	Till	Stone	Open.
2			Till	Stone	Open.
3			Till	Stone	
4			Till	Stone	Open.
5	L. T. Louis	0	Till	Stone	Open.
6		0	Till	Stone	Plank.
7	Jacob Hemmig	10	Till	Stone	Open.
8		0	Till	Stone	Open.
9	J. M. Mook		Till	Stone	Open.
10		15	Till	Stone	Open.
13			Till	Stone	Open.
14			Till	Stone	Open.
16		20	Till	Stone	Plank.
17			Till	Stone	Plank.
18			Till	Stone	Open.
20		0	Till	Stone	Open.
22			Till	Stone	Plank.
23			Till	Stone	Plank.
24	R. C. Brockman	30	Till	Stone	Open.
25	E. E. Smith		Till	Stone	Plank.
26	A. E. Lord		Till	Stone	Plank.
27		30	Till	Stone	Shed.

[a] Well goes dry.

Springs in Saybrook.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Amount used per day.
			Feet.	*Gallons.*	*Gallons.*
11		Slope	230		0
12		Slope	235		0
15		Slope	165	0.2	0
19		Valley	140		0
21		Slope	105	.5	0

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ESSEX.

POPULATION AND INDUSTRIES.

Essex, in the south-central part of Connecticut, in Middlesex County, comprises an area of 13 square miles. It is reached by the Valley branch of the New York, New Haven & Hartford Railroad, by steamboat from Hartford and New York daily during the open season, and by the Shore Line Electric Railroad from Deep River and New Haven. Post offices are maintained at Essex, Centerbrook, and Ivoryton.

Essex was separated from Old Saybrook and incorporated in May, 1854.

The population of Essex in 1910 was 2,745. The population of the town from 1850 to 1910 is shown in the following table:

Population of Essex, 1850 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1850	950	.....	.....	1890	2,035	10	.....
1860	1,764	86	.....	1900	2,530	24	.....
1870	1,669	.....	5	1910	2,745	9	.....
1880	1,855	11	.....				

The principal industries are agriculture, wood turning, and nickel plating, and the manufacture of augers and bits, bone and ivory goods, and piano keys and piano boards. Boat building, sail making, and the repair of vessels is carried on to some extent.

Water power developed along Falls River is used by manufacturing plants at Ivoryton and Centerbrook.

TOPOGRAPHY.

The topography of Essex is characterized by numerous hills about 200 feet high, rising above flat drift-filled valley floors. The highest elevation is 360 feet, in the northeast corner of the town, and the lowest elevation is sea level, along Connecticut River. The tidal flat along Connecticut River is about half a mile wide. Rock is exposed in all the hills, but in the valleys the drift is in some places more than 50 feet thick.

Connecticut River forms the east boundary of Essex and receives all the drainage from the town. Falls River enters the town at the southeast corner and flows through Ivoryton and Centerbrook to the Connecticut at Essex. The total fall within the town is about 100 feet, or about 20 feet to the mile.

The farm lands lie along Trout Brook and Falls River and comprise about one-fourth the area of the town. Woodlands comprising

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about 5 square miles occupy the borders of the town, including practically all the hills.

WATER-BEARING FORMATIONS.

Bedrocks.—The Mamacoke, Middletown, and Hebron gneisses and the Haddam granite gneiss of the Connecticut State Geological and Natural History Survey form the rock floor of Essex and appear at the surface on most of the hillsides throughout the town (Pl. XIII, in pocket). For description of water in bedrock see page 20.

Till.—Till, which consists of heterogeneous mixtures of bowlders, gravel, sand, and clay, is distributed over the rock surface throughout the western part of the town and at elevations above 40 feet in the eastern part. Its thickness ranges from a few inches to about 25 feet. The occurrence of water in the till is described on page 15.

Stratified drift.—Deposits of sand are found in the vicinity of Centerbrook and at elevations less than 40 feet surrounding the hills in the east part of the town. In the valley of the south branch of Falls River, south of Centerbrook, wells 20 feet deep end in stratified drift, and the total thickness of the deposit probably exceeds 50 feet. In the vicinity of Essex it is, however, less than 20 feet thick. The occurrence of water in deposits of this kind is discussed on page 15.

GROUND-WATER SUPPLIES.

The average depth of 16 wells measured in Essex is 15 feet, the extremes being 5 and 30 feet. Depth to water ranges from 2 to 24 feet and averages 12 feet. The total fluctuation of the water in two wells was 4 and 6 feet, respectively. Nearly all the wells in Essex end in till, but only two were said to fail. The quantity of water used, as reported for nine wells, ranges from 15 to 50 gallons per day, the average being 26 gallons.

Many small springs issue on the slopes throughout the town, but none of those observed is known to be permanent. All are gravity springs, deriving their water from very local sources, and few of them are so situated that they are of value for domestic supplies. A spring belonging to H. A. Pratt (No. 13, Pl. XIII) yielded half a gallon a minute. The altitude of the spring is 50 feet above sea level and the temperature of the water 55° F.

The drift-filled central valley of Essex is believed to contain principally stratified deposits of sand and gravel. The depth of the filling has not been determined, but it is probably more than 50 feet in the central part. The conditions are favorable for the storage of a large quantity of ground water, which could be most economically recovered by means of driven wells (p. 40).

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PUBLIC WATER SUPPLY.

A small part of Essex is supplied with water from a reservoir of the Guilford Chester Water Co. near Chester. A flat rate is charged, and no record of consumption is kept.

RECORDS OF WELLS.

Information concerning the wells of Essex is presented in the following tables:

Dug wells in Essex.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	David Gannon	Hill	280	17	15	265	
2		Hill	120	116	15	105	
3	Alfred Wilcox	Valley	250	16	13	237	6
4		Plain	110		11	99	
5		Slope	105	19.5	14.5	90.5	
6		Slope	210	18	14.5	195.5	
7	Charles Lund	Hill	260	30			
8		Flat	50	25	24	26	
9	C. C. Dibble	Slope	20	8	4.5	15.5	
10	E. A. Parker	Slope	23	12	10	13	
11		Slope	25	15	15	10	
12	H. A. Pratt	Slope	58	13	13+		
14	D. F. Doane	Flat	18	19	16	2	4
15		Plain	45	13	11	34	
16	Matt Brown	Hill	160	5	2	158	
17	W. I. Doane	Flat	33		9	24	
18	P. E. Post	Flat	30	13	12	18	
19	E. J. Pratt	Flat	15	11	9	6	
20	A. H. Pratt	Slope	40				

Map No.	Owner.	Amount used per day.	Depth to rock.	Section.	Wall.	Cover.
		Gallons.	*Feet.*			
1	David Gannon	20		Till	Stone	Open.
2			16	Till	Stone	Open.
3	Alfred Wilcox	[a] 50		Till	Stone	Open.
4				Till	Stone	
5				Till	Stone	Open.
6		30		Till		
7	Charles Lund	50		Till	Stone	Plank.
8				Till	Stone	Open.
9	C. C. Dibble	15		Till	Stone	Open.
10	E. A. Parker			Till	Stone	Open.
11		0		Till	Stone	Open.
12	H. A. Pratt	Dry.		Till	Stone	Open.
14	D. F. Doane	20		Sand	Stone	Shed.
15		25		Till	Stone	Open.
16	Matt Brown	10		Till	Board	Open.
17	W. I. Doane			Till	Stone	Plank.
18	P. E. Post	[a] 15		Till	Stone	Open.
19	E. J. Pratt			Till	Stone	Open.
20	A. H. Pratt			Till		Plank.

[a] Well goes dry.

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WESTBROOK.

POPULATION AND INDUSTRIES.

Westbrook comprises an area of 19 square miles lying in the south-central part of Connecticut, near the mouth of Connecticut River, in Middlesex County. It is reached by the New London division of the New York, New Haven & Hartford Railroad and by electric railway from New Haven. There are post offices at Westbrook and Grove Beach.

Westbrook was separated from Saybrook and incorporated in May, 1840.

The population of Westbrook in 1910 was 951. The population from 1840 to 1910 is shown in the following table. The principal industries are agriculture and fishing.

Population of Westbrook, 1840 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1840	1,182	.....	.....	1880	878	.....	11
1850	1,202	2	.....	1890	874	.....	.5
1860	974	.....	19	1900	884	1	.....
1870	987	1	.....	1910	951	8	.....

TOPOGRAPHY.

The surface of Westbrook slopes gradually toward the tidal flat, which is about three-quarters of a mile wide. The highest elevation is 350 feet.

Practically all the drainage in Westbrook enters the Sound at Menunketesuck Point through Patchogue and Menunketesuck rivers. The former drains the east half of the town and the latter the west half.

Woodlands comprise an area of about 12 square miles. The farm lands are situated principally in the vicinity of Westbrook, in the southeast corner of the town, and extend northward along Trout Brook.

WATER-BEARING FORMATIONS.

Bedrocks.—The southern half of Westbrook is underlain by rocks which have been designated in publications of the Connecticut State Geological and Natural History Survey Mamacoke gneiss, Stony Creek granite gneiss, and Lyme granite gneiss. The northern half is underlain by rocks which have been designated Middletown gneiss and Haddam granite gneiss.[1] There are a few exposures along the shore, but in

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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the northern part of the town outcrops are numerous. (See Pl. XIII, in pocket.) The occurrence of water in crystalline rocks is discussed on page 20.

Till.—Till, consisting of a heterogeneous mixture of bowlders, gravel, sand, and clay, occurs generally throughout the town. Its average thickness is about 20 feet and maximum thickness about 30 feet. The occurrence of water in till is described on page 15.

Stratified drift.—Isolated deposits of sand, 5 to 10 or 15 feet thick, occur along the west side of the valley of Trout Brook and at a few places in the northwestern part of the town. None of these deposits are extensive and they are not important as a source of ground water. Beach sand has accumulated along the shore of Westbrook Harbor, but till extends out to the water's edge at Chapman Point and on the west side of the town.

GROUND-WATER SUPPLIES.

The depth of dug wells in Westbrook, as determined by measurements of 29 wells, ranges from 9 to 29 feet and averages about 18 feet. The depth to water, measured in 31 wells, ranges from 5 to 25 feet and averages 14 feet. Four wells have shown fluctuations ranging from 3 to 6 feet. Three of the wells examined penetrate rock and three have failed during recent dry seasons. The daily consumption of water, as reported for 13 wells, ranges from 5 to 30 gallons, averaging 15 gallons. A number of wells have been dug south of Westbrook within a few rods of the shore and at elevations only a few feet above sea level. These wells range in depth from 15 to 25 feet and contain large supplies of fresh water.

In the southern part of the town are two drilled wells 40 and 135 feet deep, respectively. Both end in rock and produce good domestic supplies. One of these wells is within half a mile of the shore and ends at a point more than 100 feet below sea level. The other well is a little more than a mile from shore and extends 5 feet below sea level.

A few small springs issue on the slopes in the northern part of the town, but they are not suitably situated for use in domestic supplies. One spring (No. 33, Pl. XIII), located at an altitude of 140 feet, was found to yield 0.5 gallon of water a minute.

RECORDS OF WELLS.

The available information regarding the wells of Westbrook is set forth in the following tables:

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Dug wells in Westbrook.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	Mrs. Heflin	Flat	18	13.5	12.5	5.5	
2	H. M. Platts	Flat	30	11	9	21	
3a		Flat	30	26	24.5	5.5	
4	A. H. Reynolds	Flat	25	22	22	3	
5		Flat	30		8	22	
6	Steinbach	Flat	50	14.5	12	38	
7	W. Z. Jones	Flat	50	21	19	31	
8		Hill	30	25	23.5	6.5	
9		Flat	38	20	19	19	
10		Flat	40	13.5	12	28	
11		Ravine	120	18	16	105	
12	John Hayden	Slope	140	23	21	119	
13		Plain	210	11	9	201	4
14		Slope	160	16.5	14	146	
15		Hill	205	18.5	15	190	
16	Robert Harvey	Hill	230	15	13	217	6
17	S. E. Stevens	Slope	175	9	5.5	169.5	
18		Slope	200	14.5	9.5	190.5	
19		Hill	175	22	15	160	
20		Hill	155		12	143	
21	H. C. Schmelre	Hill	150	16	13	147	
22		Hill	120	18.5	16.5	103.5	
23		Slope	55	19	18	37	
24		Hill	30	28.5	12.5	17.5	
25	E. A. Dean	Valley	15	13	12	3	
27		Shore	15	18	12	3	3
28		Shore	12	24	12	10	
29		Shore	13	18	12	6	4
30		Shore	15	20	13	2	
31	R. W. Wright	Flat	90	10.5	9	81	
32		Slope	100	14	12	88	

Map No.	Owner.	Amount used per day.	Depth to rock.	Section.	Wall.	Cover.
		Gallons.	*Feet.*			
1	Mrs. Heflin	10		Sand	Stone	Open.
2	H. M. Platts	0		Till	Stone	Open.
3		0		Till	Stone	Open.
4	A. H. Reynolds	5		Till	Stone	Open.
5						
6	Steinbach	30		Till	Stone	Plank.
7	W. Z. Jones	10		Till	Stone	Open.
8		25		Till	Stone	Open.
9		0	20	Till	Stone	Open.
10		15		Till	Stone	Open.
11				Till	Stone	Open.
12	John Hayden	[a] 0		Till	Stone	
13		[a] 10	11	Till	Stone	Open.
14		0		Till	Stone	Open.
15		0		Till	Stone	Open.
16	Robert Harvey	10		Till	Stone	Open.
17	S. E. Stevens	15		Till	Stone	Open.
18		0		Till	Stone	Open.
19		20		Till	Stone	Plank.
20						
21	H. C. Schmelre	0		Till	Stone	Plank.
22		10	15	Till	Stone	Open.
23		0		Till	Stone	Open.
24		20		Till	Stone	Open.
25	E. A. Dean			Till	Stone	Open.
27					Stone	Shed.
28					Stone	Plank.
29					Stone	
30					Stone	
31	R. W. Wright			Till	Stone	Open.
32		[a] 15		Till	Tile	Open.

[a] Well goes dry.

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Drilled wells in Westbrook.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Amount used per day.	Depth to rock.	Quality of water.	Drilled in year—
			Feet.	*Feet.*	*Gallons.*	*Feet.*		
3	Wm. Johnson	Flat	35	40	30	10	Rusty	1908
26	John Veeser	Flat	25	135	25		Good	
34	R. H. Stannard	Slope						
35	Knough	Slope						

QUALITY OF GROUND WATER.

Both of the waters that were analyzed from drilled wells in Westbrook, though from different depths, are moderate in mineral content and fairly soft.

Analyses of water from drilled wells in Westbrook.

[Parts per million; R. B. Dole, analyst.]

Constituents.	1	2
Total solids at 180° C.	172	140
Total hardness as $CaCO_3$	57	64
Iron (Fe)	.25	.15
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	12	74
Sulphate radicle (SO_4)	10	23
Chlorine (Cl)	34	13

1. Well of Wm. Johnson (Pl. XIII, No. 3), 40 feet deep; sample collected June 14, 1915.
2. Well of John Veeser (Pl. XIII, No. 26), 135 feet deep; sample collected June 14, 1915.

OLD LYME.

POPULATION AND INDUSTRIES.

Old Lyme is situated in the south-central part of Connecticut, at the mouth of Connecticut River, in New London County. It is reached by the New London division of the New York, New Haven & Hartford Railroad (stations at Lyme and Black Hall), by steamboat from Hartford and New York daily during the open season, and by stage from North Lyme. Post offices are maintained at Lyme, South Lyme, Black Hall, and Sound View.

Old Lyme was taken from Lyme and incorporated in May, 1855, as South Lyme. The name was changed to Old Lyme in 1857. The area of the town is 27 square miles.

The population in 1910 was 1,181. The following table shows the population from 1860 to 1910. The principal industry is agriculture:

Population of Old Lyme, 1860 to 1910.

Year.	Population.	Per cent increase.	Per cent decrease.	Year.	Population.	Per cent increase.	Per cent decrease.
1860	1,304			1890	1,319		5
1870	1,362	4		1900	1,180		11
1880	1,387	2		1910	1,181		

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TOPOGRAPHY.

The south and west borders of Old Lyme are characterized by tidal flats, which reach a width of 2 miles in the southwest corner of the town. In the vicinity of Roger Lake, on the north border, a broad flat area, 50 feet above sea level, 2 miles long and 1½ miles wide, marks the position of an ancient lake. Hills produced by undulations of the rock floor and ranging in height from 100 to 260 feet occur throughout the other parts of the town. The highest point, 270 feet above sea level, is on the east border. (See Pl. XIII, in pocket.)

Connecticut River forms the western boundary and Long Island Sound the south boundary, and all the drainage enters these water bodies. The principal streams within the town are Lieutenant, Duck, and Blackhall rivers and Mill Creek, all tidal for 1 to 3 miles above their mouths. Roger Lake, 49 feet above sea level, lies partly in the town of Lyme and partly in Old Lyme; its outlet is a tributary to Lieutenant River.

The tidal flats lie along the south and west borders of the town and extend up Blackhall River to Black Hall and up Lieutenant River nearly to Laysville.

Woodlands along the west border of the town and in the central part, extending from Black Hall north to Rogers Lake, occupy about half the area of Old Lyme. The cultivated lands are situated in the valleys of Blackhall River and Lieutenant River.

WATER-BEARING FORMATIONS.

Bedrocks.—The bedrocks consist of the formations named by Gregory Mamacoke gneiss and Lyme granite gneiss.[1] The former is exposed in the hills in the eastern and southern parts of the town and the latter appears at the surface in the northwest quarter of the town. The occurrence of water in rocks of this type is discussed on page 20.

Till.—Unstratified deposits of sand, clay, and bowlders of glacial origin lie at the surface in the eastern half of the town and on the hills in the western half, except where bedrock is exposed. These deposits range in thickness from a few inches to about 30 feet and average about 20 feet. See page 15 for a discussion of the occurrence of water in this formation.

Stratified drift.—In the vicinity of Roger Lake and extending westward from the lake about 1½ miles and southward from the town line to Laysville, a distance of nearly 2 miles, is a deposit of stratified sand and gravel exceeding 15 feet in thickness. Small deposits of sand are found at several places in the valley of Blackhall River (Pl. XIII).

[1] See Preliminary geological map of Connecticut: State Geol. and Nat. Hist. Survey Bull. 7, 1907.

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GROUND-WATER SUPPLIES.

Dug wells in Old Lyme range in depth from 8 to 35 feet and average about 15 feet. Depth to water, as determined by measurements of 40 wells, ranges from 5 to 34 feet and averages 12 feet. The average fluctuation of the water table, as determined by measurements of 4 wells, is about 4 feet. Three of the wells examined penetrate rock and 3 had recently been dry. Reports for 14 wells indicated an average daily consumption ranging from 10 to 35 gallons and averaging about 15 gallons. Eight of the wells examined are not used.

Six drilled wells in Old Lyme range in depth from 90 to 314 feet. The yields were not determined but are sufficient for domestic needs. From one of these wells 30 gallons a day is used and from another 2,000 gallons a day; the other four are seldom used.

The stratified deposits in the vicinity of Roger Lake are probably thick enough to store a large supply of ground water. A public water supply is needed now and the newly constructed electric railroad will increase this demand. The utilization of the ground waters in the vicinity of Roger Lake by means of driven wells should receive consideration. The lake itself lies too low to be available for use without pumping.

RECORDS OF WELLS.

Information concerning the wells of Old Lyme is set forth in the following tables:

Dug wells in Old Lyme.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
1	.....	Flat	16	13	11	5	.....	.....
2	S. P. Monroe	Valley	35	9	5	30	.....	.....
3	B. L. Bramble	Slope	23	8	6	14	.....	.....
7	J. A. De Wolf	Flat	16	8	6	10	.....	.....
8	Black Hall School	Slope	14	13	11	3	.....	.....
9	.....	Flat	15	12.5	11	4	.....	.....
10	.....	Hill	18	14	12	6	.....	.....
11	Byron Maynard	Plain	24	12	8	16	.....	.....
12	do	Plain	30	14	14	16	3+	(a)
13	W. P. Howard	Hill	22	14	13	9	6	(a)
14	Henry Austin	Flat	18	12	10	8	.....	.....
15	H. H. Haines	Flat	18	17	16	2	5	4
16	.....	Flat	19	10	9	10	.....	(a)
17	.....	Slope	60	11	9	51	.....	.....
18	W. L. Anderson	Slope	85	10.5	8	77	.....	.....
19	Mrs. C. Roberts	Slope	30	18	16	14	.....	.....
20	.....	Flat	8	14	5	3	.....	.....
23	.....	Hill	45	15	.....	.....	2+	.....
24	.....	Hill	45	15	14.7	30.3	.....	.....
25	Leonard	Slope	70	12	10	60	.....	.....
26	Brown	Hill	135	35	34	101	.....	.....
27	G. H. Reed	Hill	173	12	.....	.....	.....	.....
28	.....	Slope	214	12	11	203	.....	.....
29	Matthew Rouland	Slope	50	10	8	42	.....	.....
30	E. J. Swaney	Slope	25	9	.....	.....	.....	.....
31	do	Slope	35	14	12	23	.....	.....
32	T. J. Dickey	Slope	32	13	12	20	.....	.....
33	.....	Plain	50	12	9.5	40.5	.....	.....
34	Mrs. Georgeanna Maynard	Plain	50	10	8.2	41.8	.....	.....
35	.....	Plain	48	11	9	39	.....	.....
36	.....	Slope	60	17	15	45	.....	.....

[a] Well goes dry.

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Dug wells in Old Lyme—Continued.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea.	Fluctuation of water table.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
38	Fred Harding	Slope	75	20	18	57		
39		Hill	110	28	21	89		
40		Slope	60	17	13	47		
41		Hill	43	32	30	13		
42		Plain	40	20	16	24		
43		Plain	50	12	10	40		
44		Slope	20	18.5	16.5	3.5		
45	E. P. Trowbridge	Slope	35	10	8	27		
46		Flat	18	13	11	7		
47		Slope	20	21	20	0		
48		Slope	60	22	18	42		
49	H. C. Pearson	Hill	208	20	16	192		

Map No.	Owner.	Amount used per day.	Depth to rock.	Section.	Wall.	Cover.
		Gallons.	*Feet.*			
1		60		Till	Stone	Plank.
2	S. P. Monroe			Till	Stone	Open.
3	B. L. Bramble			Till	Stone	Open.
7	J. A. De Wolf			Till	Stone	Plank.
8	Black Hall School			Till	Stone	Shed.
9				Sand	Stone	Open.
10				Till	Stone	Open.
11	Byron Maynard			Till		
12	do	0	14	Till	Stone	Shed.
13	W. P. Howard			Till	Stone	Open.
14	Henry Austin	30		Till, sand	Stone	Open.
15	H. H. Haines	25		Till	Stone	Open.
16		0		Sand	Stone	Open.
17		0		Till	Stone	Open.
18	W. L. Anderson	15		Till	Stone	Open.
19	Mrs. C. Roberts	10		Till	Stone	Open.
20		0		Sand	Stone	Shed.
23		0		Till	Stone	Open.
24				Till	Stone	Open.
25	Leonard			Till	Stone	Plank.
26	Brown	20		Till	Stone	Shed.
27	G. H. Reed			Till	Concrete	Open.
28		20		Till	Stone	Open.
29	Matthew Rouland	15		Till	Stone	Open.
30	E. J. Swaney	0		Till	Stone	Open.
31	do	15		Till	Stone	Plank.
32	T. J. Dickey			Till	Stone	Open.
33				Gravel	Stone	Open.
34	Mrs. Georgeanna Maynard	30		Gravel	Stone	Open.
35				Gravel	Stone	Plank.
36				Till	Stone	Open.
38	Fred Harding	20		Till	Stone	Open.
39		30		Till	Stone	Open.
40				Till	Stone	Open.
41		0		Till	Stone	Shed.
42				Till	Stone	Plank.
43				Sand, gravel	Stone	Open.
44				Till	Stone	Open.
45	E. P. Trowbridge	0		Till	Stone	Open.
46				Till	Stone	
47		20		Till	Stone	Open.
48				Till	Stone	Open.
49	H. C. Pearson	35	18	Till, rock	Stone	Open.

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Drilled wells in Old Lyme.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Yield per minute.	Amount used per day.	Quality of water.	Drilled in year—
			Feet.	*Feet.*		*Gallons.*		
4	Mrs. Clara Noyes	Flat	20			0		1911
5	L. F. Lowry	Flat	25			30		1911
6	J. A. De Wolf	Flat	20	90	Low	0		
21	Mrs. Sill	Shore	12	101		0	Iron	
22	Hale	Shore	8	160		0		
37	H. L. Hoffman	Hill	82	314		2,000		1908

QUALITY OF GROUND WATER.

The subjoined analysis shows the composition of water from a dug well supplying the house system of Fred Harding (Pl. XIII, No. 38). The water is low in mineral content and fairly soft.

Analysis of water of dug well of Fred Harding, June 14, 1915.

[R. B. Dole, analyst.]

	Parts per million.
Total solids at 180° C	110
Total hardness as $CaCO_3$	35
Iron (Fe)	Tr.
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	40
Sulphate radicle (SO_4)	21
Chlorine (Cl)	9.5

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